ENGINEERING

IBF

N

this issue SEP 9 1958

ENGINEERING
IBF

VIGATING

OSS THE POLE

GH SPEED

OTOELASTICITY

SSENGER FLOW

SUBWAYS

RVESTING

THREE YEAR

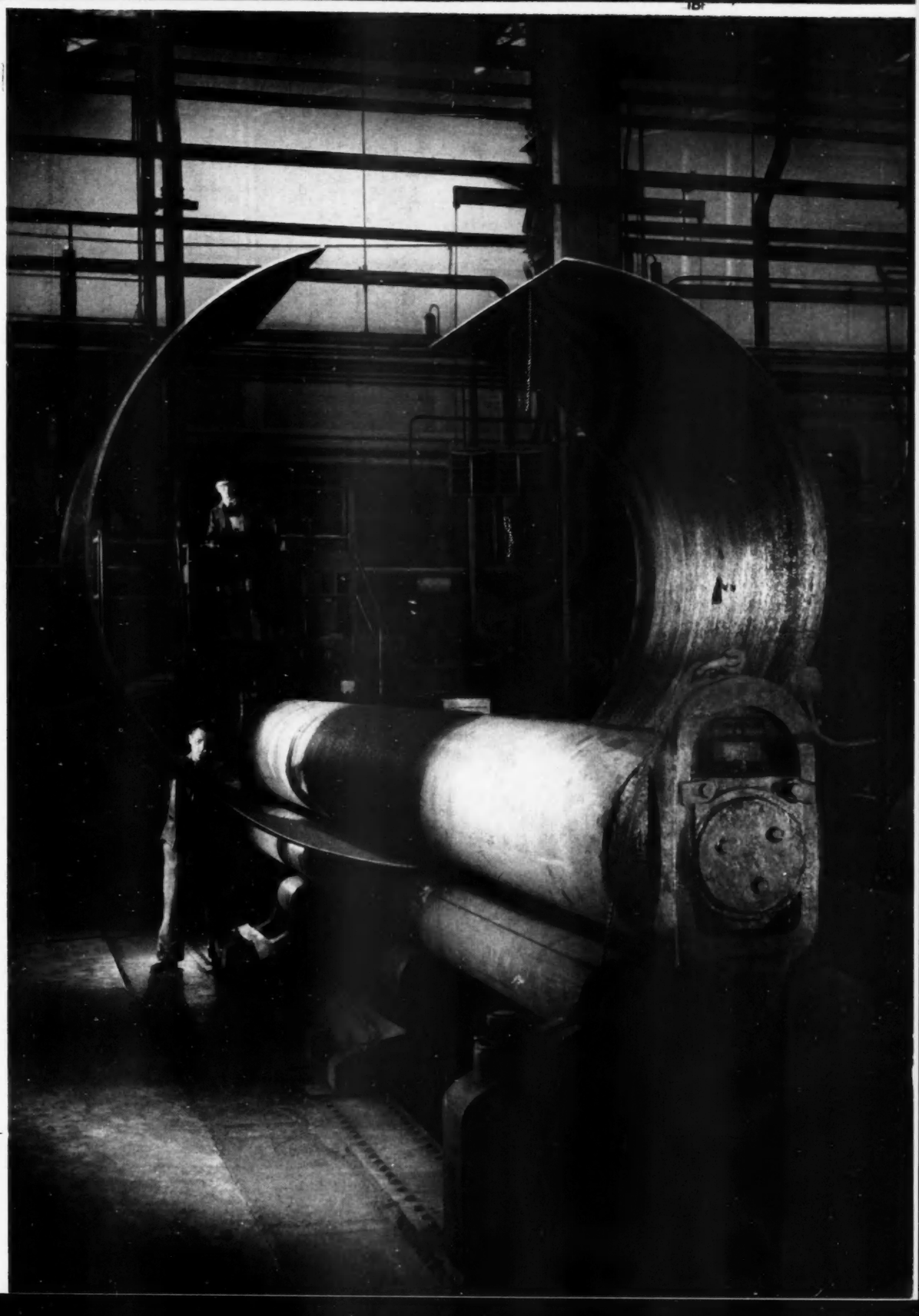
CLEAR CROP

omic Energy Exhibition

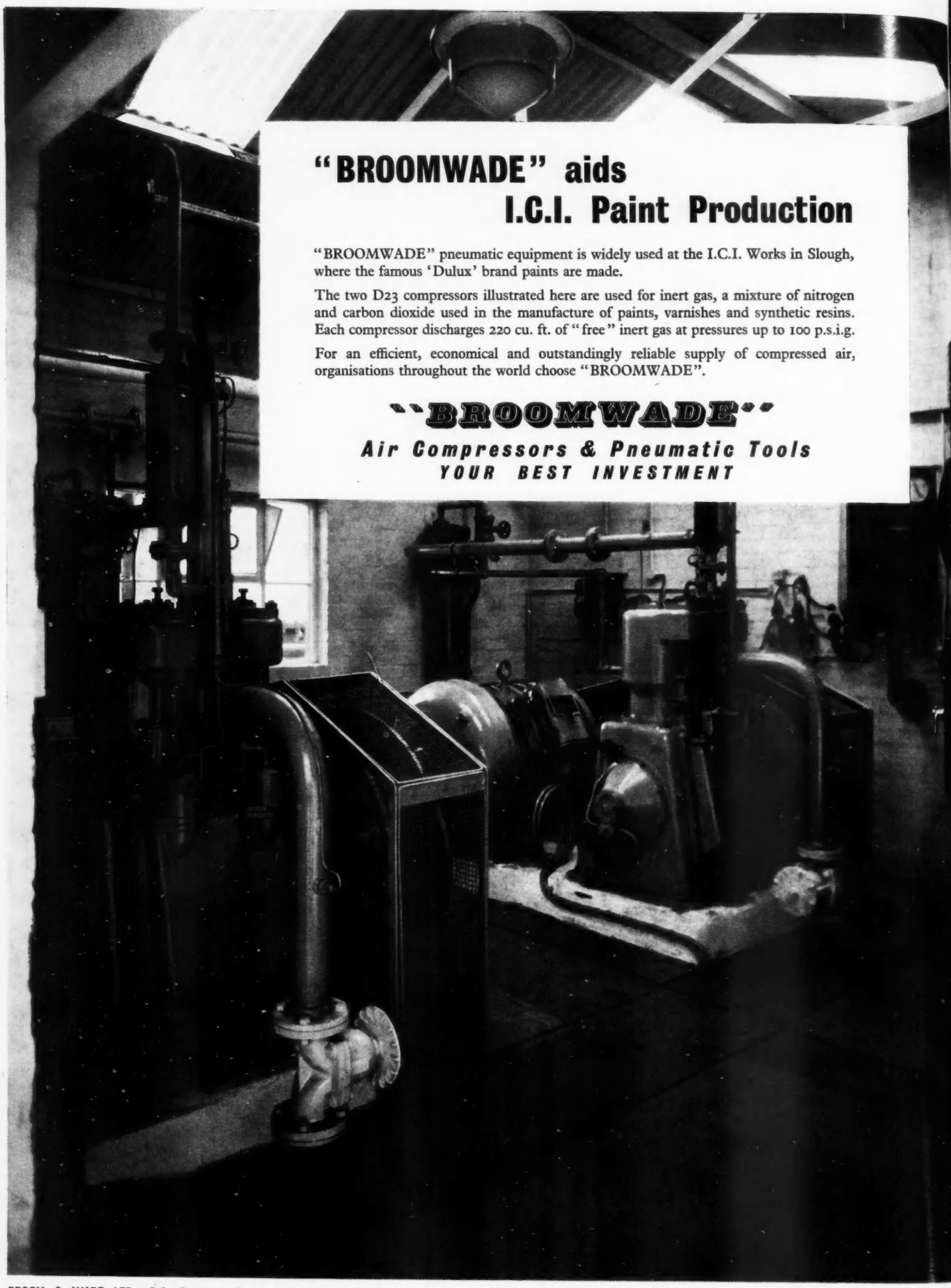
Geneva

PRICE

2/-



olling Plate for a Distillation Column



"BROOMWADE" aids I.C.I. Paint Production

"BROOMWADE" pneumatic equipment is widely used at the I.C.I. Works in Slough, where the famous 'Dulux' brand paints are made.

The two D23 compressors illustrated here are used for inert gas, a mixture of nitrogen and carbon dioxide used in the manufacture of paints, varnishes and synthetic resins. Each compressor discharges 220 cu. ft. of "free" inert gas at pressures up to 100 p.s.i.g.

For an efficient, economical and outstandingly reliable supply of compressed air, organisations throughout the world choose "BROOMWADE".

"BROOMWADE"

Air Compressors & Pneumatic Tools

YOUR BEST INVESTMENT

BROOM & WADE LTD., P.O. Box No. 7, High Wycombe, England · Telephone: High Wycombe 1630 (10 lines) · Telegrams: "Broom", High Wycombe, Telex

580 SAS

ENGINEERING

PUBLISHED EVERY FRIDAY

Vol. 186 No. 4824 22 August 1958

Contents

225 **Leading Article**
Middle-Aged Bachelor

226 **Plain Words**

227 **Letters to the Editor**
Help from the West in Iraq

228 **Obituary**
W. F. Durand
John Lamb, O.B.E.

Special Articles

232 Harvesting a Three Year Nuclear Crop: Atomic Energy Exhibits at Geneva

238 Navigating Across the Pole: Problems in Guiding Submarines

235 **Atomic Review**
Interdependence

239 **Companies in the News**

246 **Book Reviews**
Five Books on Sewage and Wastes
A History of Technology—Vol. IV: The Industrial Revolution

247 **New Books**

247 **On the Shelf**

256 **Engineering at Home**
Which? Consumer Research at Work
Golf Balls

. . . . . .

226 **Management**
Weekly Survey

229 **Plant and Equipment**
Mobile Power Plant
Telescopic Stacker
Desk Phone
Electric Crab
Insulation Meter
Dust Sampling
Thin Ball Bearings
Multi-Skip Dumper
Straddle Carrier for Road Work
Fuel Contamination Monitor
Universal Magnetic Chuck
Electric Works Truck
Lubricating Oil Distributor Pump
One Ton Hoist

240 **The Human Element**

241 **Metals and Materials**
Ignition of Firedamp by Stationary Metal Particles and Frictional Sparks

243 **Design**
Post Office Letter Sorter
Passenger Flow in Subways and on Staircases

248 **Research and Development**
High Speed Photoelasticity: Development and Application

254 **Production**
Speeding Up Commutator Assembly
Welding and Stress Relieving Facilities

255 **Construction**
Making Thames Water Drinkable: M.W.B.'s Ashford Common Filtration Works
When Will the C.E.G.B. Sell Water as a By-Product?

Middle-Aged Bachelor

A RECENT visitor to these islands remarked that as a nation we worked from Monday to Friday, but Saturday and Sunday were given over to contemplation and meditation. If he based this remark on his observations during a stay with a very religious or intellectual family there may be nothing extraordinary about it, but if, as seems likely, his sampling of English families was representative, he is an unusually generous commentator. Few Englishmen would describe as contemplation and meditation the Saturday morning shopping expeditions, the Saturday afternoon passive watching of a national game, the Sunday gardening or queue-motoring to the coast, and the frequent spells before the television screen. But perhaps there is more than a grain of truth in his comment. The week-end is, in fact, the chief time when a man can withdraw from his working routine and allow his mind to roam. Below the conscious level his brain may do a considerable amount of sorting out, even if he deliberately chooses to "forget" the office. The trivialities of the week-end may contribute to his thoughts and actions during the following week. In fact, the week-end is so important as a mental refresher that it raises a more important question—are we allowing enough time for personal education in middle life? It seems odd to make such a sharp distinction between the years of sweated education at school and university and the following years when a man is made acutely conscious of his desire for more enlightenment but is practically denied the opportunity to acquire it except by piece-meal reading, short courses and other methods of picking it up the hard way.

In a typical engineering career, the years of apprenticeship extend beyond the time of formal apprenticeship. They are followed by the years of endeavour, and then by the years of achievement. It is during these two later phases that a man may experience the strongest urge to learn. In addition to newly acquired family responsibilities, which give him an incentive outside his own ego, he now sees more clearly his own place in the profession or industry, and he can define his goal more specifically. He now wants to learn, and he knows what he wants to learn. Yet at that stage—when he could learn so much of value and learn it so quickly—he is hemmed in. He must press ahead with the immediate task, relying on imperfect knowledge. The better he is at his work, the less he can be spared. His employers actually invest money in a pension for his retirement, and he also contributes. His employers invest money, too, in plant and equipment from which they will reap the benefit over ten or twenty years. But there is no plan to invest a year or so of his time when he is thirty or forty. If his chances of living to enjoy retirement are normal, the dividend would certainly be paid on a spell away from present employment.

There are post-graduate courses—and they are slowly increasing in numbers. There are special arrangements by the more advanced firms and organisations to give extra training in middle life. There are conferences and short courses. But these are on a very small scale; they only affect a small proportion of those who might participate. Most men struggle through life with a slowly failing memory of their formal education and an increasing set in their attitudes to innovation and experiment. Thus the time cycle on which developments take place in industry tends to be derived from the cycle of generations, whereas it should spring from spontaneous communication and reception of new ideas. A man who remains in the specialised branch of engineering in which he started his career is particularly in need of a period in a stimulating atmosphere, when he can stand outside his own normal environment and see it objectively. A sizeable slice of the period should be spent in the company of people from other branches of engineering.

There are difficulties in the way of widespread adoption of such a plan. Perhaps the most serious to the individual is the fear that someone else will step into his shoes while he is away; or there may be a recession which will make his return uncertain. But there is no reason why these difficulties should not be overcome if the virtues of the system are appreciated. A national decree to retain young men for National Service for two years was accepted, though reluctantly, by industry; why then should industry not have its own form of National Service for men in middle life? Obviously, this proposal is not practical politics. But there is another way. A few firms and other organisations are already operating long courses for their senior staff, and these courses could form the beginning of a scheme of degrees for men over, say, 40 years of age. A suitable national or professional authority would have to administer the scheme and they would control the award of the degree. It would be a treasured distinction, marking those men who had taken time off to re-invigorate their minds when they were at the height of their powers. Could we call it the degree of Bachelor Refreshed?

Cover Picture. *Large cylindrical vessels are often made by bending a plate and welding the longitudinal seam. The bending is carried out with rolls as shown in our illustration; the plate is mild steel and is* 1 *in thick. The final vessel, a distillation column, will be* 10 *ft in diameter.*

(*Nurnberg photograph for* ENGINEERING)

* * *

Plain Words

It makes me despair when I hear people complain that the Welfare State deprives the individual of his personal responsibility and initiative. Funnily enough, it is frequently those very people who are afraid to lose a little of their own security in taxation—security they fondly believe to have been hard won—that are the most complaining. It would be better if instead of attacking generalities they devoted their polemic energies to the specific anomalies and iniquities of a particular welfare state.

Look at it this way. A human being seeks to relegate as many activities as he can to the realm of habit. Thus when he is typing he does not watch the keys; when he is writing he does not consider how to hold a pen; when he is eating he pays little attention to the digestion of his food; and when he is operating a lathe his hands go automatically to the controls. In the same way, if we can find a communal repository for our most tedious and fundamental worries, then we shall be better able to get on with the job. The individual who has to scratch around for his basic amenities is hardly likely to have the time to make a creative contribution to the life of his country. The scientist who is preoccupied with administative problems is frustrated and unproductive.

Most people are fully aware of this; so it is even more curious when we let them get away with their ill-considered grieving. Any army officer knows that a soldier who has domestic troubles—his wife has run off with a bartender perhaps—is a bad soldier. Most employers readily provide their employees with the benefits and facilities that will make them contented in their work.

We sometimes fail to realise that the insurance we pay to the Prudential would not protect us in our need were we alone in our providence. Independent self-sufficiency is a myth, and if protection is best provided on a national scale, then we should be suspicious not of the benefits that such a scheme affords us but of the impositions on our liberty that it may involve.

We are no longer living in a jungle, but a complex interwoven modern society—I threw away my leopard skin and firestick millenia ago. Indeed, the interdependence of our society is a prerequisite of technical and industrial growth. The ruthless competitive virtues that were desirable in Cro Magnon men are hardly to be encouraged in our youth to-day. They may take to sharpening bicycle chains.

CAPRICORN

Weekly Survey

Who Builds Diesel Locomotives?

The latest contracts placed by the British Transport Commission bring the total of main-line diesel locomotives ordered to 586. Some of this total are being built in British Railways' shops, but plenty of orders are still going to the locomotive industry. The new contracts cover 83 locomotives valued at about £8 million and the work will be divided between the North British Locomotive Company and the English Electric Company. The former are to build 33 2,000 h.p. diesel-hydraulic and 20 1,100 h.p. diesel-electric locomotives, while the English Electric Company will supply 30 2,000 h.p. diesel-electric locomotives.

The 2,000 h.p. locomotives, which have a top speed of 90 m.p.h., will be used for express passenger and freight services and the remainder, with a top speed of 75 m.p.h., are designed for mixed-traffic duties. The diesel-hydraulic locomotives complete the programme for the construction of 129 such locomotives to replace 200 steam locomotives on the Western Region, where they will be introduced in 1960. Deliveries of the diesel-electric locomotives will begin in 1960 and they will be distributed to those areas where their introduction is expected to give the most economic return.

These orders constitute the second batch to be placed as part of the accelerated programme of conversion to diesel traction: the first batch comprised 124 main-line diesel-electric locomotives ordered in July, of which 40 are being built by the Brush Electrical Engineering Company at Loughborough and the remainder in the railway workshops. The power equipment for the latter will be built by the British Thomson-Houston Company and will comprise a Sulzer diesel engine of 1,160 h.p. coupled to a B.T.H. traction generator. These locomotives are all classified as Type 2 and deliveries will begin early in 1959. The Eastern Region will receive 106 and the North Eastern region the remaining 18. July also saw the delivery of the first diesel-electric and the first diesel-hydraulic locomotives to be built in British Railways' workshops. The former, powered by a 1,160 h.p. Sulzer diesel, was built at the Derby locomotive works, which was stated to be capable of building these locomotives at the rate of one every eight days, while the diesel-hydraulic, powered by two Maybach MD 650 engines and rated at 2,200 h.p., was built at Swindon.

Spare Production Capacity

Although industrial output has remained virtually static over the past two years, many companies have been completing extensions to capacity which were put in hand during the preceding period of rapid industrial expansion. Excess productive capacity is often said to exist. Hitherto very little has been known regarding the extent of such excess capacity but some interesting light was thrown on the position in the United Kingdom engineering industries by an interim report published earlier this month by the National Institute of Economic and Social Research. The conclusions are based on interviews during the second half of July with the managements of 65 companies. These companies employ about one-tenth of the total manpower in the metal-using industries (excluding shipbuilding).

On average it was found that the attainment of full and economic utilisation of capacity would require an increase in output of about 20 per cent. This, in turn, would require about 7 per cent more manpower and an increase of 3 per cent in the average working week—figures which imply that full-capacity working would be accompanied by a substantial rise in productivity. There were, however, marked variations between different engineering industries. Ten companies were either fully occupied or had very little spare capacity, while at the other end of the scale 10 companies, producing commercial vehicles, bicycles, rolling stock (excluding diesel units, for which capacity is fully booked), light electrical equipment and machine tools said they could increase output by up to 40 per cent.

These results indicate a considerable lack of balance in the engineering industries as a whole. It would appear that in some cases reluctance to reduce the labour force or to give up factory space is slowing down the necessary adjustments. In a period of rapidly increasing demand it is natural that expansion of capacity should be given high priority, but the National Institute comments that " in the last few years perhaps too much has been spent on increasing capacity and too little on producing a given output with fewer men."

Market Research on the Common Market

An article by Dr. Annelies Zisler in the June, 1958, issue of *European Productivity*, draws attention to the fact that the institution of a Common Market and possibly of a wider Free Trade Area will compel a further intensive development of market research. The opening up of a market with a comparable population to that of the United States will in many cases call for a complete reappraisal of manufacturing methods. A European company at present producing on a job or batch basis exclusively for the domestic market might, for example, be justified in adopting mass production methods following the removal of customs duties with the introduction of the Common Market. Before this decision can be taken, however, a thorough survey of the market is required, including product tests, and analysis of demand in the larger market and of the capacity resources and sales potential of competitive industries. A plea is then made for the improvement of statistics relating to the main trends in the larger markets, together with the establishment of common methods for collecting and processing the statistics essential to market research.

The article refers to valuable guides to existing statistics, which have been published in certain European countries, for example, *Resources Statistiques pour l'Etude du Marché Belge*, published by the Federation des Industries Belges and *L'Entreprise et la Statistique*, published in France. Anyone who has had occasion to use European statistics for market research purposes, however, knows that in many cases a good deal of work is required to ensure that figures for different countries are fully comparable and although the O.E.E.C. have achieved some improvement, much still remains to be done in this field.

Important though they are as a basis for market research the co-ordination of statistics is only a small part of the problem and the article suggests that it is becoming more important than ever to co-ordinate throughout Europe the work to be done, the method to be used and the exchange of information and research findings.

Design Protection Abroad

How can a manufacturer prevent his new designs being copied by foreign competitors? Whatever form of Free Trade Area is eventually set up, this problem is certain to be one of those that will face British industrialists exporting to Western Europe. The how and why of copyright and registration protection is discussed in an article in the August issue of *Design*. In

many continental countries copyright laws already give protection to industrial designs without the need for registration. Broadly speaking, industrial designs enjoy automatic protection on the Continent to a greater extent than they do here. As Britain has ratified the Universal Copyright Convention and is a member of the Berne Copyright Union, British individuals and companies are entitled to the protection of the copyright laws of most continental countries, on the same basis as nationals of these countries.

While copyright protection is free, registration is expensive, and some idea of the relative value of registration in various European countries can be gathered from the numbers of designs registered in 1956. In rounded figures, these were Western Germany, 67,500; Switzerland, 24,000; Austria, 8,000; the United Kingdom, 8,000; France, 6,500; Belgium 2,500; Italy, 1,500; Norway, 1,200; Denmark, 750; Portugal, 600; Sweden, 50; and the Irish Repulbic, 40. As these registrations were mostly made by individuals and companies in the countries concerned, they give a useful clue to what each country thinks of its design laws. The position of Sweden is explained by the fact that registration there is only given for industrial designs of metal goods.

Supposing a British company decides to register the design for its new lathe, how does it set about it? The first step is to apply for registration in this country under the Registered Designs Act, 1949, and such action must be taken before there has been " any public disclosure of the design." This application automatically creates a six-month priority right under the Convention in respect to corresponding applications in most foreign countries. So far as the probable members of the Free Trade Area are concerned, the Irish Republic is the only exception to this rule, as there only a four-month priority term is given. Any final decision on which countries to register the design in need not be taken until towards the end of the six-month period. In the meantime, a company can, according to *Design*, " safely offer and sell goods bearing the design not only in Britain, but also in the convention countries."

In practice, any company anxious to protect its designs would be well advised to employ a patents agent. Apart from his expert knowledge of the law and of conditions in the overseas countries, an agent can save a great deal of trouble by making proper " representations " which covers pictures, diagrams and the general description of the design. Discussions between the designers, the agent and the sales staff will bring out the special features to stress about the particular product and its chances in the various markets. If the design is a good one, it is worth going to the trouble and expense of protecting it, and, in the Free Trade Area countries, protection is available and adequate.

Conditions for East-West Trade

At a time when there is a concerted move among members of the Organisation for European Economic Co-operation to relax the embargo on the export of equipment to the Soviet Bloc, an article in the July issue of the quarterly review of the Skandinaviska Banken is of topical interest. The writer, who is an official in the Swedish Ministry for Foreign Affairs and who has been chairman of the committee of financial experts who have studied trade and financial problems under the auspices of the Economic Commission for Europe, has made a number of suggestions for improving the mechanism of East-West trade.

If one can assume that the Governments of eastern Europe, and for that matter China as well, are prepared to reconsider the value and purpose of foreign trade, certain proposals can be suggested, according to the author of the article. The reassessment of the purpose of foreign trade on the part of the Eastern Bloc involves, of course, a good deal of change of policy in such matters as protection of patents, freedom of travel, freedom of economic and technical information, and a willingness to offer substantial and regular quantities of goods to the West. Granted then that this very big assumption can be made it is possible to consider improving the machinery of trading under three headings.

First, Western Europe might consider applying a liberal import licensing policy towards goods from Eastern Europe and agree to make payment in an acceptable transferable currency. This offer from the West might take place within the framework of OEEC trade liberalisation which will leave the West free to exclude certain articles and to retain rights of protection against dumping. Second, in return for this gesture, the Soviet Bloc might agree to increase its total trade with the West by certain average annual minimum percentages. Finally, eastern countries should unilaterally make a number of reforms based on liberalising communist export trade. This would involve the Soviet group in the abandonment of political pricing in its more aggressive and cynical forms. On balance, these proposals probably involve greater concessions by the East than by the West since they come dangerously close to expecting the Soviet Bloc to modify its political and economic theory in the interests of foreign trade. These ideas do indicate, however, how serious an adjustment is necessary on both sides if the easing of the trade embargo is to result in a large and continuing expansion of East-West trade.

Collecting Technical Information

With the growth of American manufacturing subsidiaries in Europe and increasing output of American products under licence, there is a tendency to belittle the extent to which American industry is itself dependent on European technical developments. The recent announcement that the Budd Company of Philadelphia, Pennsylvania, has become a sponsor of the European Technical Observation Group provides an example of the importance attached by American companies to keeping abreast of technical developments outside the United States, though many United States companies, of course, maintain technical representatives in Europe for this purpose.

The European Technical Observation Group was initiated by the Armour Research Foundation to keep United States industrial corporations informed of scientific and technical advances in Europe. It is now sponsored by more than 20 non-competing United States corporations in the fields of chemical engineering, electrical engineering, mechanical engineering, chemistry and metallurgy. A team of scientists and engineers centred on an office in The Hague is responsible for reporting back detailed information to the sponsoring companies, one observer being assigned for each group of four companies. These observers attend all important seminars, conferences, trade shows, exhibitions and technical meetings as well as reviewing scientific literature and providing translated abstracts of articles not usually published in the United States.

The Budd company itself has investments in three European companies and among its European licensees are eleven motor-vehicle manufacturers and four builders of railcars and rolling stock. It, nevertheless, evidently finds it worthwhile to join a co-operative organisation for the collection of technical information, an example which might well prove of value to many British manufacturers.

World Aluminium and the Volta

The Prime Minister of Ghana announced last week that the Volta River project, which originally envisaged the erection as a single project of a hydro-electric station and a plant to produce aluminium from the country's bauxite resources, would now be examined from the point of view of power production alone, leaving the question of the production of aluminium to be dealt with later. The Kaiser Company of America is arranging for a survey to bring the plan for the dam and electricity generating station up to date and the cost of the revision will be shared between the United States and the Ghana Government.

It has been known for some time that difficulty was being experienced in raising the necessary finance for the original scheme. As a result of the recession, world aluminium capacity already substantially exceeds demand and apart from the Volta project there are a number of proposals for new plants in many countries, including France, French West Africa, Australia and India. A group of United States construction companies held an option from the Ghana Government to develop the scheme but as early as a year ago it was announced that they had been unable to find an aluminium producer willing to operate the project, in view of the state of the aluminium market and the extensive commitments of the major producers elsewhere.

Aluminium Limited, who hold bauxite concessions in Ghana, announced in March of this year that they were not in a position to proceed with the Volta scheme immediately and would be prepared to release their concession if the scheme were implemented. They had already announced their intention to defer extensions to their Canadian plants and have a commitment to invest 30 million dol over six years in new power and aluminium projects in French West Africa which are to be developed in conjunction with the French companies Pechiney and Ugine.

The Volta River project is thus an outstanding example of the difficulty of reconciling the need for industrial development in backward countries with the realities of the world economic situation. It remains to be seen whether the power project alone will attract the necessary finance. If it does, the prospects for the establishment of the aluminium plant will be greatly enhanced.

Letters to the Editor

HELP FROM THE WEST IN IRAQ

SIR, With reference to the most interesting article by Mr. M. G. Ionides, on page 173 of your issue of 8 August, I write to support most heartily his views on development planning in under-developed countries. While I have not had a very lengthy experience of living in such territories, during my tour of service between 1953 and 1955 in a colony where the local cash crop, then commanding an exceptionally high world-market price, provided substantial funds for development projects, I was able to observe most of the phenomena described by Mr. Ionides.

The situation, faced by the local government and politicians, was of a land sorely in need of modern facilities, of a relatively backward population in the mass and of ample funds available for the purchase of equipment and technical advice. On the one hand, the politicians were strongly influenced towards development projects of a spectacular nature which would assist them in continuing in the favour of the electorate: on the other, the technical advisers, mainly ex-patriot, naturally pressed the claims of those projects which would proclaim most effectively to the technical world their authors' daring and " expertise." Minor regard appeared to be given to the needs of the mass of the population, which were for a gradual build-up of their education and technique in social organisation, of village amenities and of agricultural capacity; all such things as would provide them with a solid basis upon which an increasingly rapid progress could be built. In all fairness, mention must be made of the work of the

Continued on next page

Continuing Letters to the Editor

Community Development Department, which was encouraging the growth of good local government and of improvements in housing and hygiene in the villages: but the size of this department and the funds available to it, in comparison with other project-initiating and controlling departments, was disproportionate to the overall magnitude of the tasks to be tackled.

When listening to discussions about such territories, one often hears the clichés about "growing up from the grass roots" and "not trying to run before one can walk," and it seems a pity that the planners should so often fail to remember these sayings when formulating their proposals. While casting no aspersions upon the Volta River Project or those associated with it, I consider that schemes of that type and magnitude in the context of countries similarly situated are ill advised and that development work on the lines, which, I understand, are carried out by the World Health Organization and the Food and Agriculture Organization, or by the Indian Community Development Project, will be more truly beneficial. While such work will provide little political capital to the politician and small kudos to the technicians employed, the long view of history will proclaim the solid worth of whatever is achieved.

Yours faithfully,

B. F. P. BABCOCK.

21 Harrington Road,
London, S.W.7.
16 August, 1958.

GAS TURBINE SCHOOL TO CLOSE

The School of Gas Turbine Technology, Farnborough, which is operated by Power Jets (Research and Development) Limited, is to close on 12 December. As gas turbine "know-how" has spread around the world, so has the demand for highly specialised instruction decreased, and the number of students passing through the school has now dropped to an uneconomic level. There are still four courses to run before the school closes—an "international" course on aero and industrial gas turbines (8-26 September); an aero-engine design course (6-24 October), an industrial gas turbine course (3-21 November), and finally an introductory and practical course (1-12 December).

The Power Jets School of Gas Turbine Technology was originally founded in 1944 to instruct Dominion air force personnel in the application of the gas turbine to aircraft propulsion. At the end of the war, it was realised that the gas turbine had a wide application in industry, and the scope of the courses were widened.

The school was operated at first by the National Gas Turbine Establishment. It was taken over in 1948 by Power Jets (Research and Development) Limited, and the company's policy was to use every opportunity to demonstrate British technical ability to the world. To this end, the courses were extended and each year two international courses were included. Not only were lectures given by their own staff of technical consultants, but specialists were invited from the various firms and organisations concerned with gas turbines and kindred subjects. The International Course has been an outstanding success and during the whole period of the school's operation, there have been nearly 3,000 students from a total of 44 different countries, representing the fighting services, government research establishments, airlines, universities and manufacturing companies. Students have ranged from 17 to 63 years old, their jobs from apprentices to university professors.

The Power Jets Consultancy Department, which has increased steadily in recent years, remains available to advise on gas turbines, rotary compressors and related equipment, and to design such equipment and assist in its development and manufacture.

Obituary

JOHN LAMB, O.B.E.

Though over 40 million tons of ships are now propelled by internal-combustion engines, there must be comparatively few superintendent engineers with more than 40 years experience in the operation of this type of marine prime mover. This experience could be claimed, however, by Mr. John Lamb, O.B.E., formerly the chief superintendent engineer of the Anglo-Saxon Petroleum Company who died on 12 August.

Mr. Lamb was only 67 years of age, having been born in Forest Hall, Northumberland, in 1890. His general education was obtained in local schools, after which he was employed for a time in a Tyneside electric-lamp factory. Shortly afterwards he entered upon an apprenticeship to engineering with Clarke, Chapman and Company Limited, Gateshead, concurrently extending his technical knowledge by attending evening classes. He went to sea, when still under 21, in steamships, and obtained his First Class Board of Trade Certificate two years later. It was in 1914 that he made his first voyage in a motorship and in 1919 that he joined the Anglo-Saxon Petroleum Company as one of their seagoing engineers. Five years later, in 1924, he was appointed an assistant superintendent in the same company. He left them in 1938 to become a director of F. J. Trewent and Proctor naval architects and consulting engineers, of London.

Two years later he returned to the Anglo-Saxon Petroleum Company as their chief superintendent. It was then that he turned his attention to the possibility of using boiler-quality fuel oils in diesel engines, a development which was successfully applied, after prolonged experimental work, in the tanker Auricula, and subsequently extensively adopted; the problems encountered, and the methods by which they were overcome, were described in detail by him in papers read before the Institute of Marine Engineers. He also did much useful work on the prevention of crankcase explosions in large oil engines, and this was the subject of a paper which he presented in 1952 to the Institution of Mechanical Engineers. Latterly, he was handicapped by ill health, and some years ago relinquished the position of chief marine superintendent. He was then appointed as head of the company's marine research and development department, in which capacity he was responsible for the experimental installation of a gas turbine in the tanker Auris. It was notably successful, and led to the company's decision to take out the remaining steam-turbine machinery and the original gas turbine of the Auris, and to re-engine the vessel with gas turbines only.

As an author of text-books on the operation of marine oil engines and their auxiliary machinery, Mr. Lamb was well known, and several of his books, which were markedly practical in outlook and presentation, have been reviewed in ENGINEERING. He was a Member of the Institution of Mechanical Engineers and of the Institute of Marine Engineers, and had received from both the award of Herbert Akroyd Stuart Prizes for his papers.

W. F. DURAND *Research in Aeronautics*

William Frederick Durand, one of America's outstanding leaders in fluid dynamics and aeronautical research, died on 10 August in America. He was born on 5 March, 1859.

He graduated with honours from Annapolis in 1880 and spent seven years in the U.S. Navy, resigning to take up teaching. After four years as Professor of Mechanical Engineering at Michigan State College he transferred to Cornel in charge of the graduate school of Marine Engineering and Naval Architecture. In 1904 he went to Stanford University to take the chair in Mechanical Engineering until 1924 when he retired, under the age limit, as Professor Emeritus. He joined the Navy when propeller design had little scientific basis and this coloured his subsequent researches in the field of Fluid Dynamics. An interest in marine propellers led to an interest in aerodynamics and when the National Advisory Committee for Aeronautics was founded in 1915 he was invited to join. He served on it until 1933 having been its chairman from 1916 until the end of the war. The research facilities at Langley Field are largely the result of his recommendations.

Almost coincident with his academic retirement in 1924 he was elected President of the American Society of Mechanical Engineers and, to devote all his time to this office, he moved to New York.

From 1925 until 1930 he was a trustee of the Guggenheim Fund for the Promotion of Aeronautics and arising from this he was, from 1929 until 1935, occupied in editing the work which will always be his memorial—the six-volume *Aerodynamic Theory* containing 20 monographs and some 2,000 pages—a book so voluminous that it took a German publisher (Springer) to undertake it. From 1940 to 1945 he repeated his war effort of the First World War and was chairman of the engineering division of the National Research Council and of the N.A.C.A. Committee on Jet Propulsion.

There can have been few men who have been awarded such honours after "retirement" as accrued to Durand. In 1935 he was given the internationally-judged Guggenheim Medal "for notable achievement as pioneer in laboratory research and theory of aeronautics; distinguished contributions to the theory and development of aircraft propellers": the same year he received the John Fritz Medal. The latter is awarded after a year's consideration by a board consisting of four members each from the American Societies of Civil, Mechanical, Mining and Electrical Engineers. The Franklin Institute awarded him their Medal in 1938 and in 1944 he received the John J. Carty gold medal from the National Academy of Sciences for notable leadership in engineering work. The American Society of Mechanical Engineers of which he had then been a member for 67 years, a past-president and an honorary member, awarded him their Gold Medal in 1945. The Medal for Merit is the highest honour the United States Government can confer on a civilian. Durand received it in 1948 from General Spaatz, representing the President. In the same year he received the Wright Brothers Memorial Trophy—the first to receive this trophy "for significant public service of enduring value to aviation in the United States." He was an Honorary Member of the A.S.M.E., an Honorary Fellow of the Institute of the Aeronautical Sciences, and a Fellow of the Royal Aeronautical Society, to which body he read the Wilbur Wright Lecture in June 1918.

Comparatively few men live to the age of 99. Even fewer achieve what Durand achieved and still remain almost unknown.

Plant and Equipment

MOBILE POWER PLANT

Four mobile diesel generator sets designed for use in Venezuela in townships and works where the local permanent power station has not yet been constructed or where local supply of power is not sufficient to meet the demand, have been built by the Brush Electrical Engineering Company Limited, Loughborough, using Mirrlees JVS 16 engines. They are capable of providing power for an average township of 10,000 and are an immediate local source of electricity.

The sets consist of one trailer for generation purposes and one for transformer duties. The generator trailer consists basically of the JVS 16 turbo-charged diesel engine, site rated at 1,727 b.h.p. at 900 r.p.m., driving a Brush 1,200 kW generator with the necessary switchgear. Exhaust silencing is by means of two Burgess snubber type silencers projecting through the trailer roof.

An alarm system is provided to indicate lubricating oil high temperature, lubricating oil low pressure, high water temperature and low water flow. A fuel oil service tank of 800 litres capacity is mounted within the frame of each trailer and an engine-driven pump transfers fuel from this tank to the header tank feeding the engine fuel system. A hand priming pump is provided from the main tank to the header tank. A Petter-Reavell air compressor set powered by a PA2 petrol engine supplies an 11 cu. ft air receiver, the working pressure of the air system being 300 lb per sq. ft.

The engine generator and exciter are mounted on a combined underbase which in turn is mounted on resilient pads fixed to the trailer chassis, preventing transmission of vibration to the trailer itself. The engine is fitted with a Woodward hydraulic governor. The complete generator trailer weighs approximately 52 tons and is 50 ft long, 10 ft wide and 12 ft high.

The Brush alternator is rated continuously at 1,200 kW, 2,400 V, 60 c/s and has an overload capacity of 10 per cent for 2 hours in any 24, as also has the engine. Voltage is maintained constant by means of a carbon pile type AVR. All switchgear necessary for control and distribution of power from the unit is carried on the trailer as also is a transformer of 75 kVA which provides a 190 V 3 phase or 110 V single phase supply for all anciliary plant, lighting, etc., making it a completely self-contained unit independent of any outside supplies.

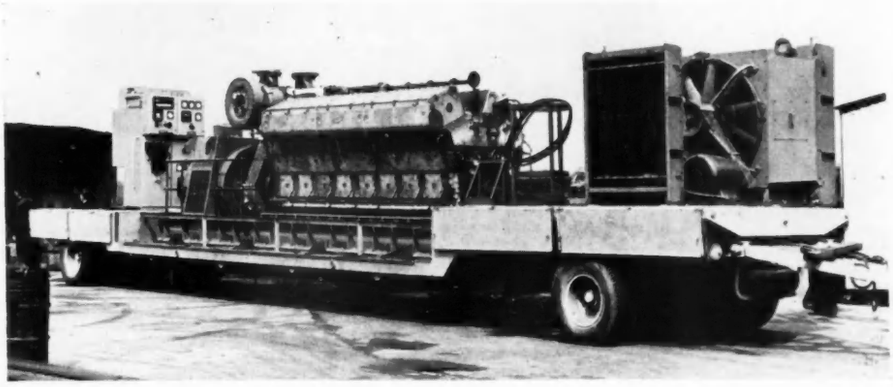


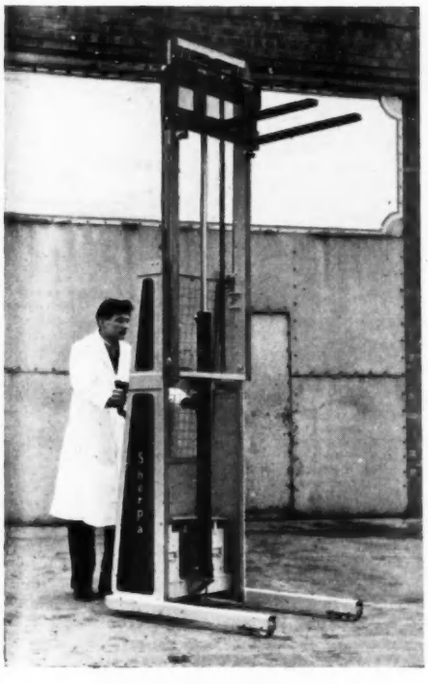
Fig. 1 Shown with roof and side panels removed, the mobile power plant is rated at 1,200 kW.

The trailer is supplied complete with its own lighting system from a 24 volt battery supply. The batteries are incorporated in the trailer with a separate charging plant. When the alternator is placed on-load a separate lighting system automatically takes over, shutting down the battery system. A master switch is incorporated to cut out all lighting during daylight hours.

Generator trailers carry a Brush 1,500 kVA transformer capable of converting the full alternator output from 2,400 volts to 13,800 volts. The transformer has an auxiliary winding for 110 volts, this voltage being used for trailer lighting. The output from the transformer is carried through a 13·9 kV kiosk type oil circuit breaker to customer's switchboard by cables 30 metres in length. The complete transformer trailer weighs approximately 10 tons, is 12 ft 6 in long, 7 ft 6 in wide, and 12 ft high.

Fig. 2 A second trailer carries a step-up transformer and switchgear.

TELESCOPIC STACKER



The model VIII Sherpa stacker that has recently been added to the range of equipment made by Salisbury Precision Engineering Limited, 1 Buckingham Palace Mansions, Buckingham Palace Road, London, S.W.1, has a capacity of 7 cwt at 15 in centres. There are two versions: A, which has a lift of 9 ft, and B which extends to 12 ft. Collapsed heights are 6 ft 4 in and 8 ft respectively.

Both models are available for either battery or mains operation, the batteries having a capacity of 96Ah. Alternative mains motors are available for 230/250 volt single-phase or 400/440 volt three-phase supplies. Speed of lift is 12·5 ft per min.

DESK PHONE

The Fonadek Interlink desk telephone system has been developed to produce the Multi-Link which forms an intercommunications system consisting of a master and four substations. Power is taken from the mains. By pressing the appropriate switch, the user can communicate directly with any one of the sub-units and each sub-unit can independently call the master by pressing a switch which rings a buzzer and lights a red indicator lamp showing which station is calling. By pressing all the switches simultaneously, the master station can call all four sub-units giving in effect a public address system. The Multi-Link is made by Fonadek (Branson) Limited, Knightsdowne House, Vivian Road, Birmingham 17.

ELECTRIC CRAB

A recent addition to the range of electric travelling crabs made by Matterson Limited, Healey Works, P.O. Box 31, Rochdale, Lancs., for overhead travelling cranes, the size 701, is designed to lift loads up to 10 tons through 33 ft 6 in. It conforms to the company's conventional design of all-steel monobloc construction requiring little headroom, and giving close hook approaches. The crab is mounted on two axles, one of which is of compensating type to ensure even distribution of the load on all four runners. The drive to the runners is through a totally enclosed oiltight spur reduction gearbox, with a friction clutch to give gradual acceleration and overload protection.

INSULATION METER

A meter is now available in this country that will measure surface resistances up to 100,000 megohms. It is made by K. P. Mundinger of Germany and the British agents are Shaw Moisture Meters, 31 Market Street, Bradford, Yorks. The meter is operated by a 22·5 volt miniature battery which is only loaded during the moment of contact. The electrodes, permanently attached to the instrument, are of highly conductive material and are designed for taking measurements on the surface of objects such as plaster or board, to indicate the moisture content. The instrument is supplied in a leather carrying case.

Continuing **Plant and Equipment**

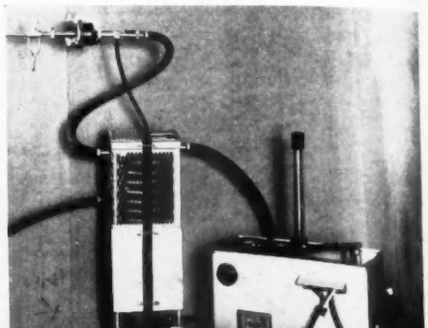
DUST SAMPLING

Regular production has now been commenced by the Longworth Scientific Instrument Company Limited, Abingdon, Berkshire, of the isokinetic sampling apparatus developed by the British Iron and Steel Research Association. "Lisa" consists essentially of the five linked units shown in the illustration—sampling probe, filter unit, cooling coil, pump units, and instrument unit. In addition, a combined pitot tube and pyrometer is provided for measuring gas velocities and temperatures.

The stainless-steel probe faces directly into the stream of dusty gas and a sample is withdrawn isokinetically, that is, it flows into the nozzle in the same direction and with the same velocity as the local undisturbed gas stream, so that the dust content of the sample accurately represents that of the main gas stream at that point. The sample is then drawn through the weighed filter and cooled to ensure that corrosive liquids are not condensed in the sampling train. Two gas-tight vane pumps, equipped with by-pass valves and connected in parallel, then expel the filtered and cooled gas sample through a gas flow-rate indicator and an integrating meter. The filter is then re-weighed, and the concentration is obtained by dividing the increase in mass by the volume of the gas sample.

In order to sample isokinetically, the gas velocity and temperature in the stack are measured with the combined pitot tube and pyrometer and indicated on an inclined gauge and millivoltmeter. Simple two-column tables are then used to relate the gauge reading to the isokinetic sampling rate, which is maintained by operating one of the by-pass valves. This method of flow-rate control is made possible by placing the meters after the pumps where gas pressures and temperatures are virtually constant.

Since rates of gas and fume emission from steelmaking processes can vary rapidly, the sampling train must collect a weighable sample of dust and fume very quickly. A robust filter assembly has accordingly been designed which incorporates a throw-away filter of graded glass fibres, held in a re-usable stainless-steel canister, the whole of which can be weighed on a chemical balance. The filter pads will filter iron oxide fume from corrosive gases at 300° C at a rate of 3 cu. ft per min, while the sampling probe and pitot tube can withstand a temperature of 650° C.



Isokinetic sampling apparatus—the five basic units.

THIN BALL BEARINGS

A range of bearings with very thin cross sections, that helps to bridge the gap between miniature bearings and the larger inch sizes, is now being made by the Split Ballbearing division of MPB Incorporated, Lebanon, New Hampshire, U.S.A. It is stated that some sizes require less than 15 per cent of the volume needed for conventional inch sizes.

Four sizes of these Midget T bearings are now in production. The thinness of these bearings, in relation to United States coins of 10 cents (silver), 1 cent (bronze), 5 cents (nickel) and 25 cents silver, is well brought out in the attached illustration. The bearings have bores ranging from $\frac{3}{8}$ in to $\frac{3}{4}$ in, with outside diameters $\frac{1}{4}$ in greater in each case. Widths on the four sizes are held to $\frac{5}{32}$ in. The bearings have the maximum number of balls possible and use a one-piece phenolic retainer.

Bearings with extra thin cross sections.

INFRA-RED PROJECTOR

Metropolitan - Vickers Electrical Company, Limited, Trafford Park, Manchester, have introduced an improved version of their standard infra-red projector. It is designed for general infra-red heating applications such as paint stoving, moisture extraction, and pre-heating. Tubular metal-sheathed heating elements are used and the projectors can be fitted end-to-end to form continuous troughs, assembled in banks, or used in angular formation.

STRADDLE CARRIER FOR ROAD WORK

A straddle carrier which has been licensed for use on public roads has been produced by the British Straddle Carrier Company Limited, 7 Chesterfield Gardens, London, W.1, now a subsidiary of Short Bros. and Harland Limited. It is shown in the accompanying illustration.

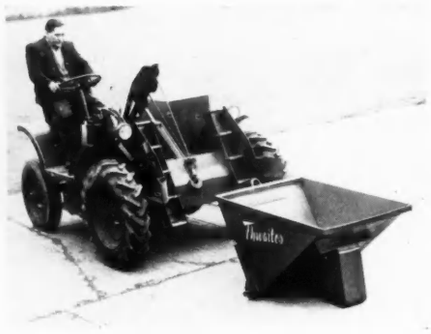
The Mark 2 has a capacity of 20,000 lb and a road speed of 30 m.p.h. when carrying 14,000 lb. The hooks clamp and lift hydraulically and have automatic alignment. Marles power-assisted steering is fitted. The vehicle is steerable on all four wheels when off the road; to comply with transport regulations the rear wheels can be locked for road working. Power is supplied by a Perkins L4 engine, developing 62 b.h.p. at 2,000 r.p.m. Six speeds are available.

The British straddle carrier Mark 2 complies with the regulationss for use on public roads.

MULTI-SKIP DUMPER

A dumper truck with a detachable skip offers many possibilities to the operator for high speed carrying. Such a combination is now available from Thwaites Engineering Company Limited, Cubbington, near Leamington Spa, and is shown in the illustration. The skip, which has a capacity of 10 cu. ft in the standard version, or 1 ton in the crane version, is attached to the truck by clips which secure it in trunnions, allowing it to be tilted for emptying. The action is hydraulic under the control of the driver who does not have to leave his seat. Alternatively, again without having to get up, the skip can be released from the trunnions by the driver and slid down the ramps to stand on the ground. The truck can then be backed away and can pick up a second skip while the first is being loaded or emptied.

To pick up a skip the driver brings the truck up to it and attaches the hook on the eye. The hydraulically-operated boom then draws the skip up the ramps and the clips lock it in place on the trunnions. When working at ground level the driver only has to lean forward to reach the lifting hook, but when the skip is below the level of the truck he has to dismount to make the connection. The jib has enough movement to recover the skip from as far as 12 ft below ground level. Several forms of skip are available.



A detachable skip enables the dumper to be utilised more fully.

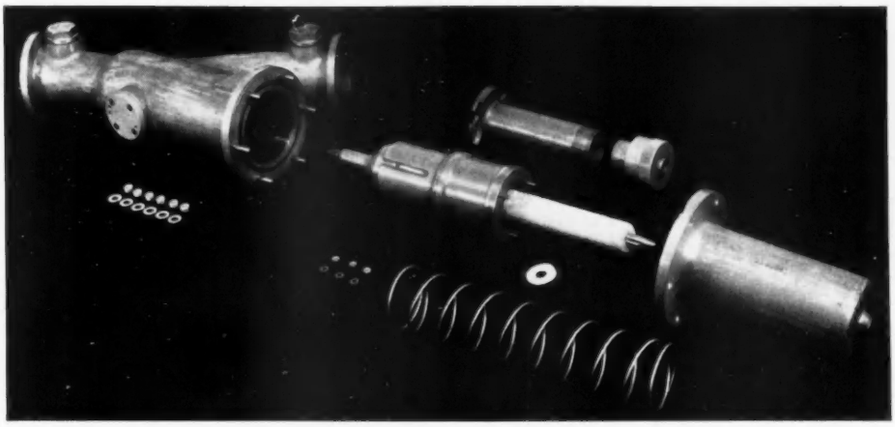
FUEL CONTAMINATION MONITOR

An automatic fuel monitor, designed by the Shell Petroleum Company Limited, in conjunction with Stream-Line Filters Limited, to prevent the slightest risk of contaminated fuel being fed into aircraft, has reached an advanced stage of development, and field trials are now in progress. Its future introduction by Shell will add another safeguard to the extensive aviation fuel quality-control system already in operation on airfields throughout the world.

Aviation fuels on delivery to an aircraft must be free from sediment, suspended matter and water, as well as meeting the physical properties of a rigid specification. Solid contaminants can effectively be removed by micro-filters, and water contamination can be avoided or detected with present-day equipment and techniques. There remains, however, the possibility of the failure of equipment or the human element. The need was felt, therefore, for an automatic monitoring device which would be both completely free from failure and situated as near to the end of the fuelling system, and hence as close to the aircraft, as possible.

The new monitor comprises a valve and sensitive element inserted in the main fuel stream to the aircraft. If contaminated fuel passes through the sensitive element the main valve closes. During normal operations the valve will open and close as the delivery valve is opened and closed, so that it is repeatedly exercised; any risk of its becoming "frozen" in the open position is eliminated.

It is also constructed so that faulty maintenance, such as a failure to replace the element, will prevent the valve from opening. The element itself is robust and casual handling cannot cause damage. The complete unit can be easily installed on existing fuellers or hydrant dispensers. The valves will be manufactured and marketed by Stream-Line Filters Limited, Ingate Place, Battersea, London, S.W.8.



An automatic monitoring device to prevent any risk of contaminated fuel being fed to aircraft is to be introduced by Shell.

The body of the magnetic chuck forms a sine bar for accurate angular positioning.

UNIVERSAL MAGNETIC CHUCK

The latest addition to the Fimax range of universal permanent magnetic chucks made by Panton and Webb, Lavender Hill, Tonbridge, Kent, has been produced for use on horizontal, vertical and jigboring machines, large surface grinders, mills, etc. It has a 14 in by 12 in chuck mounted so as to tilt about one end and also to rotate about a vertical axis. The tilting movement is controlled by a screw-operated link motion.

The chuck body, which embodies a large diameter supporting trunnion and two sine rollers, forms a 10 in sine bar so that angles about the horizontal axis may be set accurately. Two piles of slip gauges are used, one either side of the chuck, and they are nipped in position by the link motion. This feature gives rigidity under heavy loads and also allows substantial negative loads which may be produced by milling or boring.

Rotation about the vertical axis on the swivel base is on a very wide flat surface with a large diameter spigot. Setting is normally done by the degree scale, but where extreme accuracy is required a special bracket may be attached. This bracket allows a 10 in sine bar to be set up on edge and this is then clocked up from the body of the machine.

ELECTRIC WORKS TRUCK

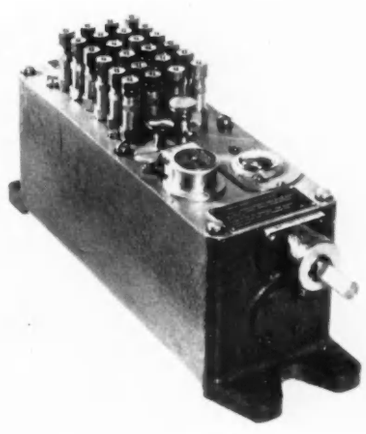
The most recent addition to the range of trucks made by Wessex Industries (Poole) Limited, Dolphin Works, Poole, Dorset, is a 30 cwt general-purpose model driven by a 2·3 h.p. motor. A fabricated steel chassis carries a 5 ft by 3 ft 6 in board platform, and the motor assembly is mounted on the steering unit at the front.

A full 90° turn in both directions is possible. With a maximum road speed of 8 m.p.h. the truck has a turning circle of approximately14 ft outside diameter, and an unladen weight of 10 cwt without the battery. A towing bracket and pin is fitted at the rear and there is ample power for towing a four-wheel trailer. There are alternative sizes of battery, with capacities of 166, 179, or 206 Ah.

LUBRICATING OIL DISTRIBUTOR PUMP

Tecalemit Limited, Plymouth, Devonshire, have introduced a 28-way distributor pump for automatic lubrication. It was designed in the first place for lubricating automatic lathes but can, of course, be used for any other machine. The standard model is shown in the accompanying illustration.

The pump itself can be adjusted to give from zero to 0·5 cc per stroke and the operating speed ranges between 12 and 1,450 r.p.m. according to the calibration of the capillaries; a hand priming knob is provided for charging the bearings when the power is off. The plunger feeds to a main gallery through the adjustment regulator which can be varied to control the delivery. Those of the output connections not in use can be blanked off. All the moving parts are submerged in the oil reservoir which holds 3 pints.



The single-spindle lubricating pump has 28 outlets.

ONE TON HOIST

An electric hoist block, arranged to lift up to 1 ton, through 23 ft at 20 ft per minute, is announced by Matterson Limited, Healey Works, P.O. Box 31, Rochdale, Lancashire. It is equipped with positive rope-guide-operated shunt and series over-winding and over-lowering limit switches. Control is by pendant push buttons, and mechanically interlocked air-break reversing contactors are under a glass fibre cover. The hoist is supplied in fixed suspension and pedestal mounting forms with push, hand chain, or power-travelling suspension trollies.

HARVESTING A THREE YEAR NUCLEAR CROP

Atomic Energy Exhibits at Geneva

THREE years have elapsed since the first International Conference on the Peaceful Uses of Atomic Energy, and during that time the exploitation of atomic energy has entered a new phase. The transition will be clear not only from the papers to be presented at the second international conference, which is to be held in Geneva from 1 to 13 September, but also from the Atoms for Peace Exhibition arranged to run concurrently. If the conference is regarded as the harvest of three years technical and scientific study, then the exhibition represents the fruit of three years engineering work.

What changes are likely to be apparent? Probably the most significant, at least as far as Britain is concerned, is the large-scale entry by commercial enterprise into a field that before 1955 was almost exclusively the domain of national bodies, engaged mainly in research. At the same time, though the fission reactor is still in its early stages, emphasis is increasingly passing from scientific research to technical development. In the last three years the first full-scale gas-cooled power reactor (at Calder Hall) and the first full-scale pressurised-water reactor (at Shippingport, U.S.A.) have come into operation, and the design and construction of their successors have been undertaken by private consortia.

The Atoms for Peace Exhibition provides ample evidence of the industry's growth. Whereas in 1955 instruments for general experimental purposes—cathode-ray display tubes, spectrometers and pulse counters, for example—dominated the display, this year there will be many more items of a specifically nuclear and engineering character—radiation monitors, particle accelerators, neutron choppers, manipulators, reactor simulators and burst-slug detection gear. Devices making use of radioactive isotopes, such as thickness gauges, will also be more numerous. Further confirmation of the movement towards practical exploitation of nuclear energy will be provided by models and diagrams of nuclear plants planned or under construction, together with their components.

Changes in the philosophy of nuclear design may also be distinguished. The view that atomic energy work requires the collaboration of specialists in several conventional disciplines is unlikely ever to be entirely superseded; but increasingly it is recognised that a project must be co-ordinated by engineers whose speciality is not civil, mechanical or electrical engineering, but nuclear engineering. The accident at Windscale may be partly attributed to the attitude, unavoidable in the early days, that a nuclear reactor is merely compound of familiar engineering elements. Had the behaviour of graphite under radiation been treated with the respect that a nuclear engineer would instinctively feel, detailed analysis of Wigner effect might have been made at a sufficiently early stage. Lord Coleraine, chairman of one of the British atomic energy groups, has recently underlined the importance of a properly integrated approach to nuclear power station design. At the exhibition, the various displays of materials developed exclusively for atomic energy work will illustrate the special requirements of nuclear engineering.

Another change in thinking concerns the diminished priority of fast reactors. Nuclear fuels, including enriched uranium, have proved so readily available that the call for reactors of high breeding ratio is no longer so urgent as was once believed. The Dounreay fast reactor, where great quantities of heat must be removed from a comparatively small core is to employ liquid-sodium cooling. But it may have no immediate successor, and the promising high-temperature gas-cooled reactor has eclipsed, at least in Britain, the sodium-graphite system. Sodium, in any case an intractable material, is therefore receiving less attention, so that equipment for pumping liquid metals may not occupy so prominent a place in Geneva as might at one time have been expected. On the other hand beryllium for fuel-element canning and ceramic and cermet fuel elements, required for reactors operating at higher temperatures, together with models of these more advanced reactors, are likely to be much in evidence.

The prospects of nuclear propulsion have been dramatically demonstrated by the trans-polar voyage of the American submarine Nautilus. Many British and overseas firms have shown interest in the marine, aircraft and portable applications of nuclear reactors, and work in this field is likely to be well represented by models and diagrams.

Finally, since Dr. Homi J. Bhabha spoke of the prospects for thermonuclear power at the first Geneva conference, Zeta and Sceptre in Britain and corresponding apparatus in other countries have taken the first steps in that direction. Equipment and models associated with thermonuclear research will be exhibited by several companies.

BRITAIN LEADS

The Atoms for Peace Exhibition will be held at the Palais des Expositions in Geneva from 1 to 14 September. Some 350 exhibitors from 13 countries are taking part, including more than 84 British companies and the United Kingdom Atomic Energy Authority. The Scientific Instrument Manufacturers Association of Great Britain will be represented by 26 member firms. The sponsors in the United Kingdom are the Nuclear Energy Trade Associations' Conference (N.E.T.A.C.), 32 Victoria Street, London, S.W.1, and the organisers are C.D. (Overseas) Exhibitions Limited, 30 Uxbridge Road, London, W.12. The British section covering 40,000 sq. ft will form the largest national display, and United States exhibitors will occupy 32,000 sq. ft. The total exhibition area will be 200,000 sq. ft. Another exhibition, designed to supplement the atomic energy conference, will be held in the Palais des Nations. The following notes discuss the industrial exhibits under sectional headings, and though emphasis is on the British display, reference is also made to other nations' contributions.

Complete Power Reactors

The five United Kingdom nuclear power groups will be exhibiting prominently at Geneva. Also taking part will be other British companies engaged in reactor work, including the two companies, which in conjunction with two American firms, market respectively small boiling and pressurised-water power reactors. The United Kingdom Atomic Energy Authority will show models and diagrams of its current and future projects, including the advanced gas-cooled reactor (AGR) represented in Fig. 1. The AGR will operate at higher temperatures than do the existing gas-cooled reactors, and for this reason will employ beryllium canning for the fuel elements. It will provide an intermediate step between the present nuclear stations and the high-temperature gas-cooled reactor which will come later. An HTGC reactor experiment is under construction at Winfrith Heath, and a model of this plant will also be on view. In the United States section there will be two operating nuclear reactors, both designed for training and research. One will be shown by the Atomics International Division of the North American Aviation company and the other by Aerojet-General Nucleonics. The United States Atomic Energy Commission will be showing a full-scale model of a reactor core destined to give an electrical output of 150 MW.

Five Nuclear Power Groups

Five consortia have been established in Britain to undertake the design and construction of complete nuclear power stations of gas-cooled graphite-moderated design for home or overseas requirements. All five groups will be represented by major exhibits.

A.E.I.—John Thompson.—On a stand of 2,000 sq. ft floor area under an overall fan-like roof will be shown the manufacturing and research resources of the A.E.I.—John Thompson Nuclear Energy Company Limited. The stand is built round four models: the Berkeley 275 MW nuclear power station now under construction; the Merlin research reactor, two of which are nearly completed in this country and another, which is the first of its size to be sold to a European country by British private enterprise; a typical 150 MW single reactor power station of a kind that can be offered for export; and Sceptre III (fusion apparatus will be discussed in another section of this article).

Around these models the constituent members of the company will show examples of their activities in the nuclear field. John Thompson will indicate how they are welding the 1,000 ton pressure vessels at Berkeley, and how they overcome the difficulties in welding 3-in steel on site. Reference will also be made to their work at Dounreay, where they built the spherical containing vessel, the liquid-metal circuits and the metal-to-water heat-exchange system. Equipment to be shown by Metropolitan-Vickers, British Thomson-Houston, Sunvic Controls and Isotope developments is discussed in later sections.

Atomic Power Constructions.—The aim of the display by Atomic Power Constructions Limited will be to demonstrate the company's ability to design, construct and commission atomic power stations of all sizes. A drawing office is included in the stand, complete with drawings of a power station for technical discussion. One exhibit illustrates the effort that the company are devoting to further research and development, and

features welded specimens to indicate how rigidly welding is specified in various parts of a reactor, together with a broad picture of laboratory layout and test facilities at the company's central research establishment. A model of a 150 MW nuclear power station, which could be supplied to the Central Electricity Generating Board of Great Britain, is also exhibited.

Exhibits of the associated concerns, Crompton Parkinson Limited, Elliott Brothers (London) Limited, the Fairey Aviation Company Limited, Richardsons, Westgarth and Company Limited, are treated below. Nuclear Civil Constructors, also members of the group, will show photographs of various civil-engineering schemes, including their part in the plutonium separation plant at Windscale; while International Combustion Limited will exhibit component parts of a heat exchanger for a gas-cooled graphite-moderated reactor, noting the items on the part-section model shown in Fig. 2. Twelve such heat exchangers would be built per station, each 84 ft high, 20 ft in diameter, and weighing 300 tons.

English Electric—Babcock and Wilcox—Taylor Woodrow.—The dominant theme of the English Electric—Babcock and Wilcox—Taylor Woodrow Atomic Power Group's stand is the group's progress on building Hinkley Point, which will be the world's largest nuclear power station with a net electrical output of 500 MW. A large transparency, 20 ft by 10 ft, will depict the station and will show a 400 ton Goliath crane lifting into position the eleventh of the twelve heat-exchanger units, and a stator for one of the six main 93·5 MW turbo-alternator sets about to be moved into the 700 ft long turbine house. A model about one two-hundredth full size will show the station as it will appear when finished, and detailed information will be given on an associated plan.

Two other models, built to larger scales will depict a reactor and a steam-raising unit. The reactor model is sectioned and will show details of the graphite-moderated core, the charge and discharge arrangements, the spherical pressure vessel, the biological and thermal shields, the coolant-gas circulation, and the heat exchangers or steam-raising units. It is based on the reactors for Hinkley Point, each of which produces nearly 1,000 MW of heat, but its general design and construction are typical of smaller reactors, which the group has developed. The model of the steam-raising unit demonstrates how higher steam output has been achieved, with relatively little increase in boiler size, by developing a greatly increased heat-exchange surface per unit volume of heat exchanger.

Display panels will be devoted to features of the Hinkley Point station which enable it to give a greater heat output without any increase in the size, thickness or strength of the pressure vessel. These features include the core supporting structure, the internal insulation of the upper part of the pressure vessel, and the smaller diameter and greater numbers of channels permitted by the higher gas pressure.

G.E.C.—Simon-Carves.—Visitors to the stand of the General Electric Company Limited and Simon-Carves Limited will be able to walk inside the full-size model shown in Fig. 3, representing part of a nuclear reactor; two of the large gas-outlet ducts can be seen. The model is of a gas-cooled graphite-moderated reactor similar to the two which will power the 320 MW nuclear power station now under construction by the two companies at Hunterston, for the South of Scotland Electricity Board. All the principal internal components will be visible, including the graphite core with its reflector, the boron sandwich shield above the core, the double-shell pressure vessel, the fuel elements, control rods, and gas-sampling tubes for burst-cartridge detection equipment.

Also there will be a sectioned model showing the working of one of the Simon-Carves steam-raising units, eight of which are installed round each reactor of the Hunterston nuclear power station. Each steam-raising unit is designed to generate 143,100 lb (55,000 kg) of steam per hour, at 580 lb per sq. in gauge (405 kg per sq. cm) and 700° F (370° C); and 70,850 lb (32,000 kg) of steam per hour at 150 lb per sq. in gauge (105 kg per sq. cm) and 660° F (350° C).

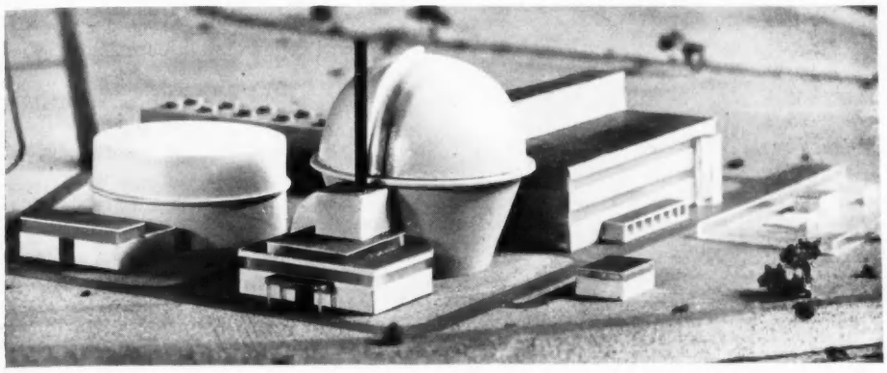
The layout of the high-temperature gas-cooled zero-energy cirtical assembly being built for the U.K.A.E.A. at its research establishment at Winfrith Heath, will be shown in an illuminated schematic diagram. G.E.C. has been awarded the contract for a large part of the design and construction of this assembly, which will constitute the first step in the practical development of a new type of reactor. Because the fuel-element design will permit the use of much higher operating temperatures, vastly improved steam conditions should be attainable and it may even be possible to operate gas turbines from such a reactor.

Plant and components for reactors made by these companies for nuclear power stations will be described in the following section.

Nuclear Power Plant Company.—The scope of the Nuclear Power Plant Company Limited will be demonstrated on the company's 2,000 sq. ft stand by a comprehensive display of models, one from each of its eight member firms. The consortium itself will be represented by a model of a 400 MW nuclear power station, shown in Fig. 4, with two reactor buildings, one animated, a fully equipped turbine house, a switch yard and other buildings. The N.P.P.C. film "Bradwell," which was awarded first prize at a recent exhibition in Rome, will be shown at frequent intervals in the stand cinema, and photographs and transparencies will depict progress at Bradwell," which was awarded first prize at a recent N.P.P.C. nuclear power station in Italy.

Some of the equipment and models contributed by member companies, C. A. Parsons and Company Limited, Clarke, Chapman and Company Limited, A. Reyrolle and Company Limited, Strachan and Henshaw Limited, and Alex. Findlay and Company Limited, will be discussed in subsequent sections. Head, Wrightson and Company Limited will be showing a model of a Bradwell boiler, Whessoe Limited a typical weld section for a reactor vessel, and Sir Robert McAlpine and Sons Limited various construction techniques for a reactor building.

The stand will also include a "nuclear propulsion corner," where a model of a ship will be displayed by Swan, Hunter and Wigham Richardson Limited. This concern recently signed an agreement with the N.P.P.C. regarding collaboration on marine nuclear power units.



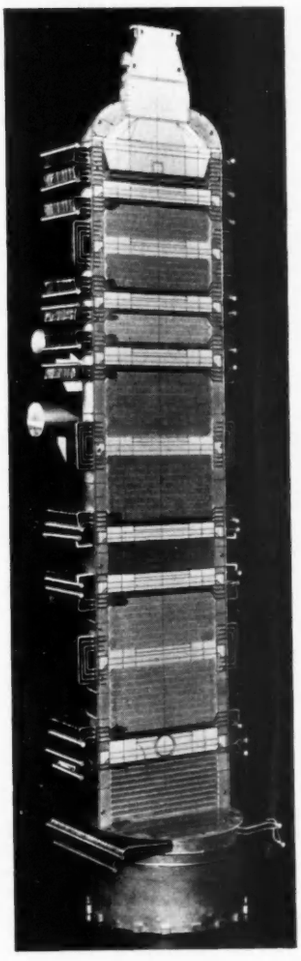


Fig. 1 (above) Model of advanced gas-cooled reactor project (AGR) to be undertaken by the United Kingdom Atomic Energy Authority this year.

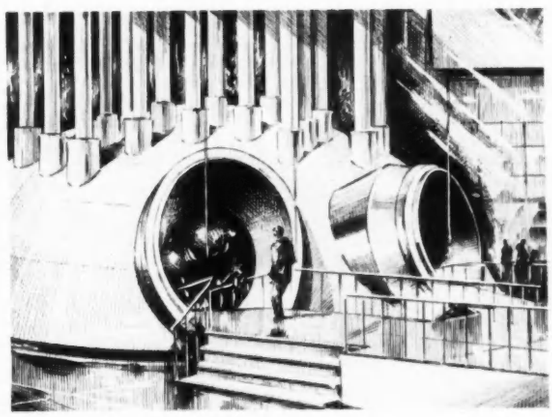


Fig. 2 (left) Model of a typical heat exchanger for a 500 MW nuclear power station showing tubes and headers. (International Combustion Ltd.)

Fig. 3 (above) Full-scale model representing part of a reactor similar to those being built by G.E.C. and Simon-Carves at Hunterston.

Companies Making Small Reactors

British companies have also established themselves in the field of smaller power reactors; in particular those designed for marine or aircraft propulsion, or for areas not easily served by a grid system where local power requirements are less than 100 MW. Apart from those companies mentioned

Continuing Harvesting A Three Year Nuclear Crop

below, Hawker Siddeley—John Brown Nuclear Construction Limited are concerned with the development of reactors for portable or propulsion applications.

De Havilland Nuclear Power Group.—As part of the de Havilland Engine Company's policy to investigate developments having possible application to aircraft or missile propulsion, a nuclear power group was formed, whose interest also extends to smaller power plants for portable or similar applications. A significant result of the company's investigations into small highly-rated systems was the conclusion that high-temperature gas-cooled reactors, using ceramic fuel elements with the primary coolant at about 800° C passing directly to a gas turbine, might be made competitive with conventional prime movers in the electrical output range 10 to 30 MW.

Layout of the de Havilland stand will be centred on a high-temperature gas-cooled loop and associated equipment under construction for the Atomic Energy Research Establishment. The loop is designed to test a new kind of ceramic fuel element in the PLUTO high-flux research reactor in conditions of radiation, temperature, pressure and atmosphere resembling those it would meet in operation. The coolant gas in initial experiments will be helium, and a secondary cooling system employing carbon dioxide has been incorporated to provide adequate cooling in the event of primary-circuit failure. All-welded components and circuits ensure a high degree of leak tightness. The de Havilland stand will include a one-twelfth scale model of PLUTO, sectioned as indicated in Fig. 5, to indicate the layout of the loop, together with perspective sectional drawings to illustrate details of the fuel-element tube assembly and associated equipment.

In addition there will be an air bearing rig comprising an electrically energised rotative assembly mounted on self-acting gas journal bearings; illuminated drawings and a full-size model of small high-speed gas circulators incorporating self-acting gas bearings under development for the HTGC loop; and components of control and shut-off valves for use in radioactive gas circuits.

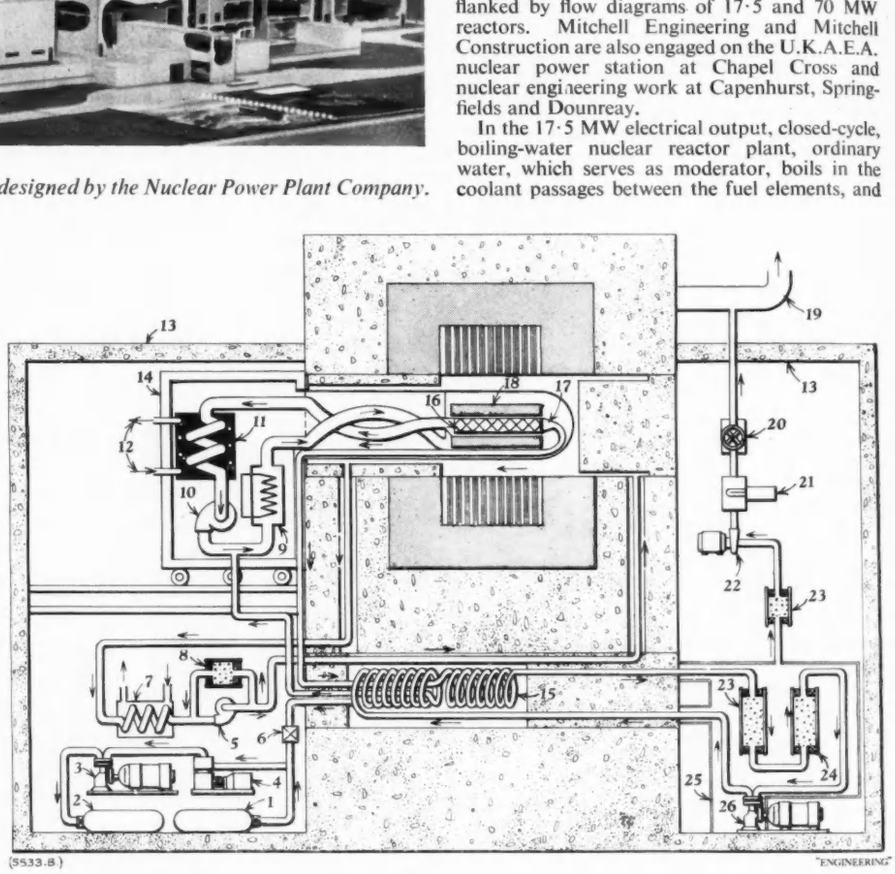
Humphreys and Glasgow.—The package power reactor in the range 5 to 20 MW (electrical) will be represented by Humphreys and Glasgow Limited, who offer for sale plants of this size built entirely in Britain. The company holds world rights outside North America for the Alco pressurised-water reactor, based on the plant built for the United States Army at Fort Belvoir, near Washington, which has been operating successfully for 16 months. A similar plant is now to be built at Fort Greely, Alaska, with twice the thermal output. Nuclear engineers from the British company will be at the Alco Products Incorporated stand.

An illuminated panel will display a cross-section of a 50 MW Alco reactor which can be used as a source of steam or incorporated in a power station to give an electrical output of 12·5 MW and which has a wide field of potential applications. There will also be a panoramic model of a newly designed package nuclear plant, the components mounted on skids for easy assembly. The plant is shown in the setting of an overseas mining site in mountainous country, for which such installations are said to be ideal. A working control-rod drive mechanism of a reactor will also be on view. Another exhibit will be a special sine-wave heat exchanger designed to withstand the wide temperature fluctuations experienced in nuclear power plants. (See Alco Products.)

Mitchell Engineering.—Also representing the small-reactor field are Mitchell Engineering Limited, who offer plants in a wider range of power output. The company are principal contractors for stations of from 17·5 to 140 MW (electrical) in association with the American Machine and Foundry Company of New York. The reactors employed may be of closed or open-cycle boiling-water design, and a model of a 17·5 MW closed-cycle boiling-water reactor, as illustrated in Fig. 6, will form the centrepiece of the Mitchell stand. The main exhibit will be flanked by flow diagrams of 17·5 and 70 MW reactors. Mitchell Engineering and Mitchell Construction are also engaged on the U.K.A.E.A. nuclear power station at Chapel Cross and nuclear engineering work at Capenhurst, Springfields and Dounreay.

In the 17·5 MW electrical output, closed-cycle, boiling-water nuclear reactor plant, ordinary water, which serves as moderator, boils in the coolant passages between the fuel elements, and

Fig. 4 Model of 400 MW nuclear power station designed by the Nuclear Power Plant Company.



(1) Clean gas containers
(2) Active gas containers
(3) Gas compressor
(4) Vacuum pump
(5) Carbon-dioxide circulator
(6) Shut-off valve
(7) Carbon-dioxide cooler
(8) Delay vessel
(9) Helium heater
(10) Helium circulator
(11) Helium cooler
(12) Water
(13) Shielded containment rooms
(14) Shielded trolley box
(15) Flexible connector
(16) Ceramic fuel element
(17) Gaseous fission-product take-off
(18) Graphite heat shield
(19) Exhaust gas duct
(20) Shut-off valve
(21) Activity monitor
(22) Exhauster fan
(23) Fission-product delay vessels
(24) Gas purifier
(25) Secondary containment vessels
(26) Compressor

Fig. 5 (above) Flow diagram for the high-temperature gas-cooled reactor fuel element testing loop being built by the de Havilland Engine Company for installation in PLUTO.

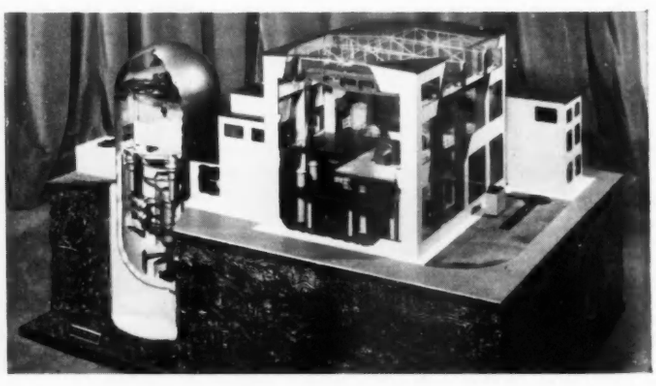


Fig. 6 (right) Model of a 17·5 MW (electrical) closed-cycle boiling-water reactor plant. Mitchell Enginering undertake construction of similar reactors.

steam is piped to intermediate heat exchangers, the condensate being discharged through circulating pumps back to the reactor vessel. The fuel is uranium dioxide pellets clad in stainless steel. The reactor design is reported to be particularly flexible, so that future developments may be incorporated. The core support structure, for instance, is designed so that it can be easily and completely removed from the reactor vessel, and the biological shielding is based on the assumption that the heat output may be increased twofold. The core (5 ft in diameter and 5 ft high) comprises 164 uranium dioxide fuel assemblies, enriched to 3 per cent in the uranium 235 isotope, and has 13 cruciform control rods.

The heat output of the reactor is 58·5 MW and the operating pressure is 900 lb per sq. in, with steam operating temperature of 533° F (278° C.). The turbine main inlet valve pressure is 600 lb per sq. in and the temperature 489° F (254° C). (See A.M.F.(Atomics).)

Vickers Nuclear Engineering.—The exhibits of Vickers Nuclear Engineering Limited will depict the work of Vickers Limited and of Foster Wheeler Limited, who, together with Rolls-Royce Limited, comprise the nuclear company. Vickers Nuclear Engineering are interested in developing the type or types of reactor which will prove the most economic in the fields of marine propulsion, small power stations (15 to 50 MW) and aircraft propulsion. They are to build for the British Admiralty the prototype nuclear reactor and machinery for submarines and the hull installation of the nuclear machinery in H.M.S. Dreadnought. The reactor is of pressurised-water design. Though not strictly applicable in the present peaceful context, the knowledge gained is useful in the design of reactors which might prove economic in a merchant ship. The pressurised-water reactor has proved reliable and flexible in operation. For the submarine project Vickers N.E. has built, and is operating with the U.K.A.E.A., two research reactors, LIDO and NEPTUNE, and has also constructed a variety of loops, radioactive and non-radioactive, for nuclear research and for experiments in heat transfer, corrosion and other problems using both water and liquid metal.

At the exhibition a model of the LIDO reactor will be shown together with photographs of the original reactor in use at A.E.R.E., Harwell. Other models include an advanced gas-cooled reactor in a supertanker and a pressurised-water reactor in a large tanker. There will also be models of steam-water separators and the "chevron" steam dryer, together with samples of materials and techniques.

American Reactor Firms

United States companies will also be showing examples of reactor plants, in addition to the operating reactors mentioned at the foot of column one, page 228.

Alco Products.—The Army Package Power Reactor (APPR) built by Alco Products Incorporated is of pressurised-water design and has now been operating for 16 months. A similar but larger plant is to be built in Alaska, and Alco also offer small power stations of this kind in the range 5 to 20 MW. Alco are understood to have supplied equipment for virtually every atomic installation in the United States including the Manhattan Project, the Nautilus and the Shippingport nuclear power station, together with systems currently under development. (See Humphreys and Glasgow.)

A.M.F. (Atomics).—Open- and closed-cycle boiling-water reactors are represented on the stand of A.M.F. (Atomics), a branch of the American Machine and Foundry Company of New York. They have as design consultants Dr. Walter H. Zinn's General Nuclear Engineering Corporation of Dunedin, Florida. Dr. Zinn was director of the Argonne National Laboratory from 1946 to 1956, and the designer of the experimental boiling water reactor (EBWR) which has recently exceeded three times its scheduled output. (See Mitchell Engineering.)

Combustion Engineering.—The exhibit of Combustion Engineering Incorporated features a mural presentation of the company's facilities for research, development, design, manufacture and test of complete nuclear reactor systems for stationary and marine power plants. Illuminated cutaway views will show the 100 MW fast-breeder, sodium-cooled reactor for the Enrico Fermi atomic power plant and the 60 MW pressurised-water reactor for the Shippingport atomic power station. Other sections of the exhibit will illustrate the manufacturing facilities for core components which are produced by the C-E Nuclear Division in Windsor, Connecticut, and for heavy reactor components built by the C-E Nuclear Components Division at Chattanooga, Tennessee.

Combustion Engineering has been engaged in a wide range of nuclear activities since 1946 when studies were undertaken to determine the feasibility of power generation from nuclear fuels. Since then the company has served as consultants and designers for the United States Atomic Energy Commission and electric power companies on reactor system components. It has designed and manufactured reactor vessels, steam generators, shield tanks, rotating plugs and nuclear cores. Notable among the heavy components produced to date are the reactor vessel, end closure and internals for the Shippingport plant; and the reactor vessels, internals and rotating plugs for the Power Reactor Development Company's fast-breeder reactor, (Enrico Fermi plant). Work currently in progress includes the fabrication and assembly of five complete reactor cores and a number of reactor vessels and steam generators.

Locating the Exhibitors

The addresses and stand numbers of the companies referred to above are as follow.

A.E.I.—John Thompson Nuclear Energy Co. Ltd., Crown House, Aldwych, London, W.C.2. (Stand No. 103.)

Alco Products Inc., Schenectady 1, N.Y. (Stand No. 46.)

A.M.F. (Atomics), American Machine and Foundry Company, Madison Avenue, New York 16, N.Y. (Stand No. 47.)

Atomic Power Constructions Ltd., 28 Theobalds Road, London, W.C.1. (Stand No. 101.)

Aerojet—General Nucleonics, San Ramon, California. (Stand No. 28.)

Combustion Engineering Inc., 200 Madison Avenue, New York 16, N.Y., U.S.A. (Stand No. 39.)

De Havilland Engine Co. Ltd., Leavesden Aerodrome, Leavesden, Nr. Watford, Herts. (Stand No. 127.)

English Electric—Babcock and Wilcox—Taylor Woodrow Atomic Power Projects, Cambridge Road, Whetstone, Nr. Leicester. (Stand No. 123.)

G.E.C.—Simon-Carves Atomic Energy Group, Magnet House, Kingsway, London, W.C.2. (Stand No. 124.)

Hawker-Siddeley—John Brown Nuclear Construction Ltd., 4 The Sanctuary, London, S.W.1. (Stand No. 141.)

Humphreys and Glasgow Ltd., Humglas House, Carlise Place, London, S.W.1. (Stand No. 46.)

Mitchell Engineering Ltd., 1 Bedford Square, London, W.C.1. (Stand No. 131.)

North American Aviation, Atomics International Division, Canoga Park, California. (Stand No. 49.)

United Kingdom Atomic Energy Authority, 11 Charles II Street, London, S.W.1. (Stand No. 122.)

Vickers Nuclear Engineering Ltd., Vickers House, 6 Broadway, London, S.W.1. (Stand No. 145.)

(*To be continued*)

Atomic Review

Interdependence

INTERNATIONAL agreements are sustained by the good faith of the contracting parties, but often, unfortunately, survive only as long as the interests of all such parties continue to be served. In technical affairs, however, agreements frequently lead to interdependence, as in the case of international power distribution schemes, so that, once committed, a country cannot easily withdraw from its undertaking. The progress of atomic energy has spawned a wealth of international associations, from bilateral agreements for the exchange of information to world-wide agencies concerned with the distribution of nuclear fuels and the pursuit of research. The network so created has led to an interdependence that may have considerable significance for the future of mankind. The approach of the International Conference on the Peaceful Uses of Atomic Energy to be held in Geneva provides a suitable context in which to discuss recent international nuclear affairs.

References on International Nuclear Bodies

Previous references to international bodies concerned with nuclear energy appeared in Atomic Review on 17 Jan., 14 Feb., 21 March and 4 July, 1958; and 15 March, 19 April, 17 May, 22 June, 30 Aug., and 11 Oct., 1957. Other articles of related interest were published in ENGINEERING, vol. 181, pages 397 and 542, and vol. 182, page 475, 1956. The organisations mentioned include CERN, Euratom, the European Atomic Energy Agency, OEEC, and the International Atomic Energy Agency.

IAEA Review

A stock-taking of the International Atomic Energy Agency's first eight months of operations is contained in the report the board of governors is presenting to the second session of the general conference, which convenes in Vienna on 22 September, 1958. The annual report, covering the period from the end of October, 1957, to the end of June, 1958, is now being distributed to the Agency's 66 member governments. "The main work of the first eight months," the report states, "has been the establishment of an international secretariat competent to undertake many of the Agency's functions. A start has also been made in implementing certain parts of the initial programme and experience is showing that the recommendations of the Preparatory Commission provide a sound and realistic basis for the Agency's operation. By the end of the year the preparations already made will begin to bear fruit, and in 1959 it should be possible to make a first assessment of results and to explore new fields of work for the Agency under its statute."

Euratom Situation

The total capacity of the eight power reactors built, under construction, or planned in the six Euratom countries will be in the region of 660 MW, according to the "Report on the Situation of the Nuclear Industries in the Community," which the Euratom Commission has submitted to the European Parliamentary Assembly. Of these reactors (five in France, two in Italy, and one in Belgium), the only one in full operation is reactor G1 at Marcoule, France, which is still of an experimental character. The maximum installed nuclear power capacity of the Community by 1965 will probably be in the region of 3,500 to 4,000 electrical MW.

The total number of research reactors built, under construction, or planned is 25 (nine in France, seven in the Federal German Republic, four in Italy, three in the Netherlands, and two in Belgium). Of these, seven are at present in operation (five in France, one in the Federal German Republic, and one in Belgium).

The uranium output at present available to the six Euratom countries is less than 700 metric tons a year, compared with 8,000 tons a year in the United States and a probable output of 10,000 to 15,000 tons a year in Canada. But current output is expected to increase greatly, and the Community has access to large reserves that will reduce import needs, once they are put into production.

Existing projects are unlikely to achieve by

Continuing Atomic Review

1967 the Community's target of 15,000 electrical MW set by the *Target for Euratom* report, aimed at stabilising net imports into the Community by 1963.

Euratom Fusion

As part of its 215 million dol research programme, Euratom is to devote 11 million dol to fusion research, according to Professor Amaldi, chairman of the Euratom Scientific and Technical Committee.

CERN's Year

Further extensive details of the 25 GeV proton synchrotron under construction at Meyrin, Switzerland, for the European Organisation for Nuclear Research (CERN) are given in the 1957 annual report of the organisation. Known as the Eurotron, this machine was illustrated diagrammatically in Atomic Review, 30 August, 1957, and 22 June, 1956, and the entire site at Meyrin on 12 October, 1956. The interior of the ring building of the Eurotron is shown in Fig. 1. As previously reported the 600 MeV synchro-cyclotron came into operation in August last year.

Of special interest during the year have been studies of new ideas for accelerators. One approach is known as " beam stacking "; another is a plasma ring accelerator proposed by Budker and one device, closely resembling Zeta, is shown in Fig. 2. In this scheme the magnetic field inside a high electron current thread forming a closed ring is used to guide particles which can be accelerated to high energies. The main advantage of the scheme over conventional accelerators lies in the possibility of obtaining stronger guide fields, and therefore smaller radii of curvature of the accelerated particles. The primary difficulty, which has to be overcome before such a scheme becomes a practical possibility is the formation of a very thin high-current plasma thread, having sufficient stability and lifetime to permit one acceleration cycle. Budker's proposal is based on self-constriction of a high-current electron beam the space charge of which is partially compensated by positive ions. It seemed reasonable to form such a beam starting with a neutral plasma in a toroidal chamber situated in a betatron-type field which is used to accelerate the electrons in the plasma and so produce the required circulating current.

Theoretical studies have been made of the conditions for obtaining continuous acceleration of electrons (" run-away " electrons) in a plasma (against friction due to collisions with ions), and of the mechanism of self-constriction, which is an oscillatory phenomenon in general.

Experimental studies have begun with an air-cored betatron which has been designed and constructed complete with a condenser bank (about 10^3 joule of stored energy) for powering it, and the necessary timing and triggering circuits. The toroidal chamber of the betatron (26 cm orbit radius) can be filled with hydrogen plasma produced by a gas discharge at one point on the circumference which spreads around the torus guided by a longitudinal magnetic field. The properties of this plasma are being measured at present and about 10^{10} to 10^{11} electrons per cm length of the toroidal chamber have been obtained. If all these electrons are accelerated to relativistic velocities, the resulting current would be 50 to 500 amperes.

Costs of European Nuclear Research

The income required by the European Organisation for Nuclear Research for the calendar year 1958 will be 56 million Swiss francs, or about £4,660,000, towards which the British Government is to contribute one-quarter.

Commonwealth Conference and Co-operation

Invitations have been sent by the British Government to all the member countries of the Commonwealth to send delegations to a Commonwealth Conference of nuclear scientists to be held in the United Kingdom from 15 to 20 September, 1958.

Fig. 1 (above) Interior of ring building for the 25 GeV proton synchrotron being built for CERN and known as the Eurotron.

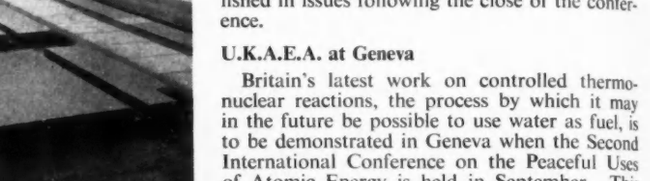


Fig. 2 (right) New approaches to the acceleration of charged particles under investigation by CERN include the plasma ring accelerator.

The programme, which starts the day after the Geneva Conference finishes, is being arranged by the U.K.A.E.A. and the C.E.G.B. It will include a two-day visit to Harwell, where the main discussions will be held, and a visit to Bradwell, Essex. The conference will then visit Calder Hall and Dounreay.

The parliamentary proposal to initiate discussions with Commonwealth Governments on the need to create a Commonwealth atomic energy organisation, somewhat on the same lines as Euratom, has been provisionally rejected.

U.K. and U.S. Exchange Information

The United Kingdom and United States have signed an agreement for exchanging atomic-energy information previously classified. The agreement is concerned primarily with military applications but may also be significant from a civil point of view. Under the agreement Britain will buy a reactor for a submarine and will receive fuel for operation of this plant over a period of 10 years. The agreement took effect from 4 August.

Nuclear Agreements with Japan and Portugal

In the recent atomic energy agreements signed with Japan, Britain and the United States have the right to reprocess irradiated materials until such time as Japan has developed adequate facilities of her own. The resulting fissile materials that are in excess of Japan's own needs may be purchased by Britain or the United States. Britain undertakes to use these materials for peaceful purposes only, the United States does not. Tenders by certain British groups are to be submitted for an improved Calder Hall reactor of 150 MW capacity. An atomic energy agreement, similar to those concluded by the United Kingdom with Sweden and Germany, is reported to have been signed between Portugal and the United Kingdom in London.

At Geneva

Some 15 specialists have undertaken to prepare special reviews for ENGINEERING, summarising the content of papers presented at the Second International Conference on the Peaceful Uses of Atomic Energy. The reviews will be published in issues following the close of the conference.

U.K.A.E.A. at Geneva

Britain's latest work on controlled thermonuclear reactions, the process by which it may in the future be possible to use water as fuel, is to be demonstrated in Geneva when the Second International Conference on the Peaceful Uses of Atomic Energy is held in September. This work will be one of the main themes of the scientific exhibition which is to be held concurrently with the conference in the grounds of the Palais des Nations. Not only will there be large-scale models of Zeta and Sceptre, the torus shaped machines at Harwell and A.E.I., Aldermaston, but there will be a working model of apparatus now in use at the Atomic Weapons Research Establishment. In this exhibition, one of two taking place in Geneva at the same time, the United Kingdom Atomic Energy Authority has taken 5,000 sq. ft of space. In addition to the fusion work there will be sections demonstrating the reactor research programme, some aspects of power research, the technology associated with nuclear development, including surveying for raw materials, research into fuel elements, instrumentation for various purposes, reactor chemistry, chemical processes and fission product disposal. Among the models of reactors on view will be the high-temperature gas-cooled experiment at Winfrith Heath and the nuclear power stations now being built for the Central Electricity Generating Board.

In the commercial exhibition being held concurrently in the Palais des Expositions, the Atomic Energy Authority is occupying 3,500 sq. ft of the total 47,000 sq. ft devoted to United Kingdom exhibits. The practical aspects of nuclear reactors, instruments and materials available for sale are complemented in the Authority's stand by an emphasis on the fuel-element service which can support the export of reactors, together with the developments in isotope production and sales service. Backed by films, with multi-language sound tracks (English, French, German

and Italian) these subjects are widely covered by means of actual exhibits, animated diagrams, models and photographs. In the fuel-element section is a display of elements spanning many years ranging from the earliest types to those being designed for future reactors. Another part of this section shows the complexity of fuel-element production from the raw material to the specialised operation of reprocessing the highly irradiated fuel elements. In the isotope section representative examples of several hundred radio-active isotopes prepared by the U.K.A.E.A. will be displayed.

U.K. Film

In order to show the developments which have taken place in the United Kingdom during the past three years a new film " More Power from the Atom," has been made and will be shown for the first time to delegates and visitors to the conference.

U.K. Papers

During the conference itself, 87 British papers will be read of 200 which have been submitted. From all countries over 2,000 papers were submitted and although the bulk of these will be included in the official report of the proceedings only a little more than 25 per cent will actually be read. British papers on thermonuclear research will include a survey of work in the United Kingdom given by Dr. P. C. Thonemann of Harwell as well as a separate paper on the design and performance of Zeta, prepared by Dr. Thonemann, three of his colleagues at Harwell and two representatives of Metropolitan Vickers Electrical Company Limited, Manchester. There will also be a paper on the theoretical problems associated with Zeta, a review of the A.E.I. research work, studies of high-current gas discharges at high rates of build-up, a study of hydromagnetic disturbances in a plasma and a short theoretical study of the stability of a constricted gas discharge. The other papers cover a wide field of work in many nuclear sciences including studies of various types of reactor, reviews of experiences with Calder Hall, the designs which have been evolved from the Calder Hall model, the economics of nuclear power, specialised applications of radioactive isotopes, safety aspects, and other subjects.

U.K. Delegation

The official United Kingdom delegation will be led by Sir John Cockcroft, Member for Scientific Research of the United Kingdom Atomic Energy Authority and the other members will be Sir Leonard Owen, Managing Director of the U.K.A.E.A. Industrial Group, Sir Willis Jackson, representing British industry, Sir George Thomson, nominated by the Royal Society, and Dr. J. F. Loutit, Medical Research Council. There will also be about 250 advisers including the authors of papers, and about 300 observers.

The President of the Conference will be Professor F. Perinn, of the Commissariat à l'Energie Atomique de France, and the Secretary-General, Dr. S. Eklund of Sweden.

British and American Firms at Geneva

The Atoms for Peace Exhibition will be held at the Palais des Expositions in Geneva from 1 to 14 September. Reference to some of the 84 British and 56 United States exhibitors is made in the article beginning on page 232.

Notes and News

Fast Reactor Agreement

The United Kingdom Atomic Energy Authority have recently concluded an agreement with Power Reactor Development Company of Detroit, U.S.A., for the exchange of information concerning the development of fast reactors. The Authority have built an experimental fast reactor at Dounreay which will be put into operation during 1959. The Power Reactor Development Company are constructing the Enrico Fermi I atomic power plant, which is a fast reactor, at Lagoona Beach, Monroe, Michigan. The Enrico Fermi plant, which is larger than the Dounreay plant, is scheduled to come into operation in late 1960. The agreement, which comes into force on 1 October, 1958, is for a period of five years.

B.N.E.C. Admit Marine Panel

The British Nuclear Energy Conference—set up in 1955—has announced that its membership has been increased to nine constituent bodies by the addition of the Joint Panel on Nuclear Marine Propulsion. Large tankers and submarines are two types of ships on which nuclear reactors are considered to be economic power units. The Joint Nuclear Marine Propulsion Panel itself consists of four bodies—the Institute of Marine Engineers, the Institution of Naval Architects, the Institution of Engineers and Shipbuilders in Scotland, and the North East Coast Institution of Engineers and Shipbuilders. The present chairman of the B.N.E.C. is Sir Josiah Eccles. The B.N.E.C. will be represented by Sir Willis Jackson at the Second International Conference on the Peaceful Uses of Atomic Energy in September.

Nautilus and Skate

The news of Nautilus's arrival at Portland on 12 August was immediately followed by a report that the Skate, the third U.S. nuclear submarine to be commissioned, had also completed a polar transit. The submarine, shown on page 238, reached the North Pole on 11 August and later surfaced in an icefield 40 miles from the Pole to communicate its achievement. It was continuing its under-ice exploration. Launched in May 1957, the Skate created a transatlantic underwater record last March when she crossed from the United States to Britain in 8 days 11 hours. In May, she set up an endurance record by remaining submerged for 31 days 5½ hours. The Skate is somewhat smaller than the Nautilus and the Triton now building. Another submarine, the Seawolf, originally equipped with a sodium-cooled reactor, is understood to be now fitted with a new reactor of pressurised-water design.

The significance of these voyages has been described as both military and commercial; besides the immense reduction in sailing distance between, say, Tokyo and London, made possible by this route, the use of nuclear submarines would permit the increased hydrodynamic efficiency of submerged navigation. Reference to the voyage of the Nautilus was made in ENGINEERING last week (pages 193 and 205). A discussion of the problems involved in navigating across the Pole appears on page 238 of this issue.

Engineering in Nautilus

Commander W. R. Anderson, captain of the Nautilus, told a representative of ENGINEERING last week that the Nautilus had already completed some 68,000 miles on her second fuel charge. Asked whether the charge was almost spent, since the first refuelling had been carried out after about 60,000 miles, he replied that the second reactor core was much superior to the first, and the submarine could travel several thousand miles more before another charge would be necessary. On board the Nautilus, the submarine's engineering officer gave ENGINEERING details of the propulsion plant.

Primary System.—The reactor compartment equipment includes one reactor, and two primary loops, of which only one loop is shown in Fig. 3. The reactor supplies heat to the primary coolant, water, which is then forced through the boiler heat-exchanger tubes, where it gives up heat to form steam on the shell or secondary side of the boiler. The primary coolant is then pumped back into the reactor where its temperature is again raised. The water from the starboard and port loops mixes together in the reactor, but the rest of the plant is divided into identical units port and starboard. The primary coolant water is kept pressurised to insure that boiling will not take place in the reactor.

Secondary System.—The secondary system is the steam system. It is completely isolated from the primary system since the primary water goes through the tubes of the boiler while the secondary water, which boils to form steam, is on the shell side of the boiler. Steam rises from the boiler to the steam drum where the water carry-over is separated from the steam. The dry saturated steam then flows back to the engine room where it drives ship service turbo-generator sets (SSTG), coolant turbo-generators sets (CTG) and the main propulsion turbines. Provision is made for declutching the propulsion turbines and reduction gears from the propeller shafts so that the ship can be driven through the water by electric motors mounted integrally on the propeller shafts. The electric motors can receive power from the battery, from small diesel engines or from a.c.-d.c. motor generator sets.

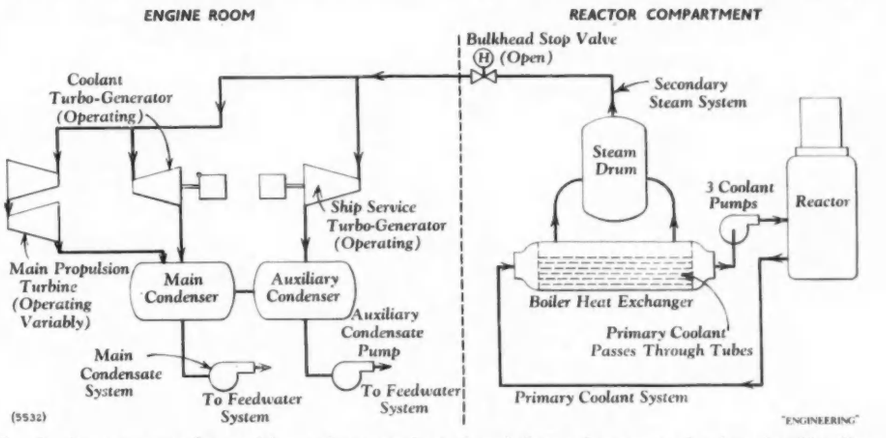


Fig. 3 Arrangement of propulsion and power plant aboard the nuclear-powered submarine Nautilus.

Radiation.—When the reactor is in operation, the lower level of the reactor compartment is kept isolated and personnel cannot enter this space. Within a few minutes after shutdown the lower level reactor compartment can be entered to perform maintenance work. The shield of the Nautilus reactor reduces the radiation to a level such that, during a cruise lasting the life of the reactor, the average crew member will receive less radiation than he would during a lifetime from X-rays and cosmic rays and natural radioactivity in the sea, air, drinking water and ground. In one year of operation the average crew member received less than the Bureau of Standards allowable radiation dosage for one week.

Start Up.—A typical schedule for start-up from cold is as follows. Four hours before getting under way, one man starts a pre-critical check of all reactor equipment. The in-port watch in the engine room and reactor compartment check systems lined up for operation. Two hours before under-way time, engineering duty section stations the watch; and the withdrawal of control rods begins. One and a half hours before under-way time, the reactor start-up is completed, followed by warming up of primary loop and steam lines. Thirty minutes before being under way, turbines are warmed up and turbo-generator sets are put in operation. Fifteen minutes before under-way time, crew are ready.

Navigation.—Nautilus is fitted with four compasses of various types including an inertial-guidance system, based on the use of accelerators in conjunction with a gyroscope, the signals being processed by a computer (see page 238).

Special Article

NAVIGATING ACROSS THE POLE

Problems in Guiding Submarines

By a Representative of the Sperry Gyroscope Company

Accurate navigation of the warship must be regarded as standard in any modern navy. It is essential both for preventing the ship running into danger and to enable it to complete its military missions effectively. The methods used are reliable and well tried. However, the advent of the world's first true submarine, the atomic-powered Nautilus, has raised in an acute form the problem of navigating while completely submerged for long periods. This problem is even more difficult when navigation is attempted under the strategically important polar ice cap.

It is worthwhile looking firstly at the methods which can be used for submerged navigation at normal latitudes. The simplest is dead-reckoning, using speed through the water to give distance and the gyro-compass for direction. The relative speed of the ship can be measured with sufficient accuracy but a considerable amount of guessing must be done to allow for tidal and ocean currents. Information on these is usually only at all accurate in coastal areas. The gyro compass indicates heading relative to true north usually with an accuracy better than $\frac{1}{2}°$. Another simple method is by use of the echo sounder. The ship's position can be fixed if a unique series of soundings can be identified on the chart. Alternatively, a course can be made along a marked contour line. This again is likely to be more accurate in coastal waters where soundings are accurately and fully marked. Other methods using conventional instruments are available, but depend to some extent on skill and special circumstances. It will be readily understood that a great deal of effort is being devoted to the development of new methods, particularly in the United States.

Astro-navigation is being developed for use when submerged at periscope depth. In the SCAR system (submerged celestial altitude recorder) the altitude of the celestial bodies is observed automatically from the periscope, and the information is transmitted by a synchro system to a computer. A horizontal reference is taken from the gyroscope. Development is proceeding also on the possibility of using the direction of radio waves received from the stars to give their altitude. The problem here, is to get a sufficiently high signal to noise ratio with an acceptable size of aerial. A submerged submarine is capable of receiving long-wave radio signals and there is a possibility of using a long-wave version of the Loran receiver, if such a system was made available.

An important new system of navigation has been developed recently for military applications —inertial guidance. The system is completely self-contained within the vehicle and neither transmits nor receives information from external sources. It is ideally suited for a submerged submarine. It is based on the principle of double integration of acceleration with time to give displacement.

The apparatus is complicated and a number of different systems are possible. An accelerometer measures the acceleration of the vehicle, and a signal proportional to acceleration is applied to an integrator which, for example, may be a Velodyne system. The Velodyne runs at a speed proportional to acceleration and the displacement of the shaft is a measure of vehicle speed. The shaft rotation can be converted again to a voltage and applied to another integrator; the output will be proportional to the distance travelled by the vehicle.

The output of the accelerometer has no significance unless its measuring axis is maintained in a fixed direction, and this is clear, particularly when the earth's gravitational field is considered. If the accelerometer is allowed to tilt by a small angle it will measure a component of gravity which is indistinguishable from a horizontal acceleration. The accelerometers are therefore mounted on a platform which is isolated from vehicle motions by gimbals and stabilised by gyroscopes. This stabilisation calls for very low-drift gyroscopes. For example, if the accelerometer is allowed to tilt by one minute of arc, a false horizontal acceleration is measured of $\frac{1}{3{,}440}g$ which gives an error of the order of 10 miles after one hour. The practicability of inertial guidance has depended entirely on the development of very accurate components, gyroscopes, integrators and accelerometers.

Of these navigational methods, only dead-reckoning and inertial guidance can be considered at the present time for navigation under the polar ice and with dead-reckoning there is a special difficulty in determining the ship's heading because the gyro-compass is not suitable for use in the immediate vicinity of the pole. This can be understood by examining the normal operation of the gyro-compass. Fundamentally, the north seeking property depends upon the interaction of gravity and the earth's rotation upon a bottom-heavy (or top-heavy) gyroscope. The action can be visualised by imagining a freely gimballed gyroscope with the weight attached to the bottom of its rotor case and with its axis of spin horizontal, pointing North-South. It will be seen that in this condition the weight cannot apply precessing torque to the gyroscope. However, if the spin axis deviates from the north, the earth's rotation causes the spin axis to tilt and the weight imposes a torque on the gyroscope, and the direction of rotation of the gyro rotor is chosen so that this torque precesses the gyro spin axis back towards the north.

It will be seen that when close to the pole the spin axis must deviate a long way from the north before the tilt due to earth's rotation can precess it back. The behaviour of the gyro-compass when navigating across the pole can be summarised as follows. The north-seeking control becomes weaker until it is zero at the pole and the compass behaves increasingly as a free gyroscope, that is it shows an apparent azimuth drift equal to the earth's rotation. Having crossed the pole, the ballistic control applies a reverse torque and the heading tends to reverse through 180°. The gyroscopic precession is slow and the compass takes a vary long time to settle on to a north heading again. Current developments have immensely improved the accuracy of the gyro-compass but this basic difficulty remains. A practical method of obtaining the fixed azimuth datum across the pole is by the use of a free gyroscope with its spin axis horizontal and compensated for the earth's rotation. The length of time for which this can be useful is limited by the random drift of the gyroscope.

Navigation under the polar ice is likely to be limited to dead reckoning methods, using a low-drift free gyroscope as the azimuth datum. Inertial guidance may be regarded as the fully automatic form of dead reckoning, where the distance travelled is derived from double integration of acceleration instead of from integration of speed through water. The importance of the submarine as a ballistic missile launching platform will almost certainly lead to more intensive development of these navigational methods.

SPERRY INSTRUMENTS IN NAUTILUS

U.S.S. Nautilus, which arrived at Portland, England, on Tuesday, 12 August, after the first underwater crossing of the North Pole, had a wide range of Sperry navigational equipment installed. Three separate systems of navigation were employed, each being used to cross-check the other two. Firstly, there was the North American Aviation SINS (ship's inertia navigation system) a three-axis inertia navigation system, the first of its kind to be installed in a combatant ship. The basis of the other two systems "estimated" and "dead-reckoning" was the information provided by Sperry gyro-compass equipment comprising two types of naval gyro-compass and an aircraft type of directional gyro from the Sperry C.11 Gyrosyn compass.

At Portland the Navigating Officer of Nautilus stated that the Sperry gyro-compasses functioned perfectly normally up to a latitude of about 88° to 89° north, that is some 100 miles from the Pole, a remarkable performance for a gravity-controlled marine gyro-compass. From 89° N inwards across the Pole to 89° N outwards, heading information was derived from the Sperry C.11 Gyrosyn compass functioning as a free gyro. This C.11 compass equipment was originally designed as a precision pyro-magnetic compass for aircraft use with a free wander rate of the gyro of less than 0·5° per hour. It incorporates the new revolutionary Sperry "Rotorace" bearing technique which very substantially reduces friction errors.

It was reported that at the Pole itself the position established by all three systems of navigation corresponded exactly. Later, when it was possible to take a "solar fix" after 1,830 miles (96 hours) submerged, the vessel's position was within less than 10 miles of that established by dead-reckoning, estimated and the SINS.

The trip was said to have been planned before the ship was fitted with the inertial system in March, and it was completely feasible on the basis of the Sperry gyro-compasses and directional gyros fitted in the submarine. Also fitted in U.S.S. Nautilus is a Sperry automatic course and depth keeping control system and a Sperry celestial altitude recorder which is used to monitor the other navigational systems.

Following the achievement of the Nautilus, the smaller nuclear-powered submarine Skate, shown here, completed a similar transit of the North Pole beneath the ice cap.

Companies in the News

Readjustment in Aircraft

Somewhat irreverently, perhaps, but not without some justification, Mr. Eric Turner, chairman of Blackburn and General Aircraft, likened the readjustment of the aircraft industry to a game of musical chairs. "The music has stopped," he said, "and those companies which have chairs remain in the competition." His own company have a chair all to themselves and had had a good year with a profit of over £1 million. The production of the Beverley transport aircraft for the R.A.F. has been the mainstay of this relatively small member of a sorely-tried industry. Their output in other fields includes buildings, lawn mowers, road rollers, agricultural equipment, pumps and compressors.

The major item of readjustment in the industry is undoubtedly the association of Bristol Aero-Engines and Armstrong Siddeley Motors. The resultant company, Bristol-Siddeley Engines Limited, constitute a formidable aircraft engine production unit, with a good range of power plants, including the Armstrong Siddeley Sapphire, Viper, Double Mamba, and the Bristol Proteus, Orpheus, Olympus and Thor. The company claim that they constitute "a new giant of immense capability, immediately equipped with the research, design, development and production facilities to lead the world in air power." There is certainly no other unit, except Rolls-Royce, to compare with them in size and these two could well form the core of British aircraft engine capacity. Whether this will be followed by a parallel alliance between the airframe interests of the two groups is possible though not, perhaps, very immediate.

The annual report of the British Overseas Airways Corporation, however, makes clear that they cannot bear what is described as "the added disadvantage of carrying an exceptional burden of expense and responsibility whenever they have been called upon to introduce a new British type of aircraft into service." They point out that no other country expects its airlines to bear the expense of developing a new aircraft to make it fit for competitive service and export. Whether or not private ventures can be successful without BOAC or BEA's help is doubtful, even where the largest groups are concerned. Perhaps the only solution is for the State to carry the burden, as in other countries.

Success for Rectifiers

The results of Hackbridge and Hewittic Electric Company Limited for the year ended 31 March suggest that they are beginning to reap substantial benefits from the modernisation in their manufacturing facilities carried out during the past few years. Group trading profit rose from £435,000 in 1956-57 to £481,000 during the year in question. Their output of mercury-arc rectifiers was a record, and that of transformers, particularly those of largest sizes, was considerably increased. The firm's chairman, Mr. Anthony M. Browne, told the shareholders that the benefits accruing from capital expenditure, development work, and the resulting improved designs, offset the rise in certain costs, thereby enabling the company to avoid the reduction in profit margins, which now affect the engineering industry as a whole.

The task facing the company at the present time is to get enough orders to keep their newly-expanded capacity fully employed. So far, they have done well with large equipment and are assured of a full year's production. Orders for small-capacity rectifiers and transformers are coming in at a satisfactory rate and full production will be maintained if they continue to do so. On the whole, it would seem that the group will do well during the current year, in spite of the slowing tempo of demand for most electrical-engineering products. There is no doubt that most manufactures take far more selling than they did a year ago, and a considerable effort is required in sales promotion.

Special developments in the product field are expected to provide Hackbridge and Hewittic with some new lines of expansion in the future. Among these may be mentioned new types of mercury-arc rectifiers with greatly improved spare factors, advances in plate-type rectifier design, and germanium rectifier units. The chairman also referred to the manufacture of high-power quartz lamps and to the development of a range of overhead-line switchgear. These technical advances are expected to provide the necessary impetus for further expansion and to enable the company to do well, in spite of a possible reduction in demands for their traditional products.

Credit for Industry

The virtual end of the credit squeeze is enabling the banks and finance companies to resume their task of helping industry to sustain growth. One of the largest of these, United Dominions Trust Limited, have produced a booklet describing their development since 1 May, 1919.

The growth of U.D.T., who pioneered and expanded hire purchase finance in this country, has been phenomenal. In 1958 their capital and reserves topped £10 million and assets are more than £90 million. The importance of their activities to the engineering industry is considerable. Through their subsidiary United Dominions Trust (Commercial) Limited, they financed until the war the sale of a considerable volume of electrical equipment and appliances. This company now conducts the bulk of the group's hire purchase business. Another subsidiary, Credit for Industry Limited, exist to provide capital for small to medium concerns, repayable over any fixed period up to 10 years. Among the subsidiaries is an engineering firm, Laystall Engineering Company Limited, acquired in 1952 "to provide a 'hedge' against the threat of another major war." This precision engineering concern brings within the group first-hand experience of the type of problems to be expected in the engineering industry, which should prove most valuable.

U.D.T.'s field of operations is world-wide. More than any other company they have made possible sales on credit of engineering products and have thus played a major part in the expansion of the industry since the first world war.

No Limit for Marine Diesels

A 12-cylinder diesel engine developing 15,000 b.h.p. at 115 r.p.m. and capable of giving a 32,000 ton tanker a speed of 16 knots is being tested by Burmeister & Wain in Copenhagen. The makers claim that no unit as large as this has ever been designed by another builder. Hitachi in Japan, building B. & W. diesel engines on licence through Mitsui, have already delivered one engine of this size. It is installed in the 33,500 ton tanker Yuyo Maru V and has given satisfactory service during the ship's first nine months at sea. Several 12-cylinder B. & W. engines are also under construction with licences in Sweden, France, Spain and Japan. Altogether there are at present some 30 such engines on order.

The makers consider this to constitute a major development in ship propulsion. It is, they say, the natural consequence of the rapid development which B. & W. started in 1952 when they introduced the first turbo-charged two-stroke diesel engine. This created a possibility for the application of diesel engines in far larger vessels than hitherto, and was therefore of primary importance to large tankers. There are at present more than 100 tankers of over 30,000 tons deadweight under construction or on order, two-thirds of which will be equipped with turbo-charged B. & W. diesels.

Some of these vessels will be powered by diesel engines even larger than 15,000 b.h.p. In 1957 B. & W. designed a two-stroke turbo-charged engine with a cylinder bore of 840 mm ($33\frac{1}{16}$ in) and a piston stroke of 1,800 mm ($70\frac{7}{8}$ in), which in continuous service will develop over 1,700 b.h.p. per cylinder at 110 r.p.m. A 12-cylinder version, developing 22,000 b.h.p. is shortly to be installed in a tanker of 45,000 tons dw ordered by Petrofina. Extensive modernisation and extensions of the company's engine works are being carried out at their Christianshavn plant at a cost of 150 million kroner (£7·75 million). The extensive nature of the changes that B. & W. are now putting through is a confident backing to their contention that "there are no longer any limits to the marine application of diesel engines."

Marine Turbine Agreement

Parsons Marine Turbine Company Limited, which is a member of the Richardsons Westgarth Group, announce that they have concluded an agreement for technical collaboration on the design and manufacture of marine steam turbines, with Brown, Boveri and Company Limited, Baden, Switzerland. Parsons Marine Turbine Company's knowledge of the design, manufacture and operation of marine steam turbines and associated reduction gearing extending over half a century, and Brown, Boveri and Company's experience of steam turbines for land purposes, coupled with extensive research facilities, provide a useful combination of resources for the development of marine steam-turbine power units.

Compagnie Electro-Mecanique, Paris, who have been collaborating for more than fifty years with Parsons in the marine field, and with Brown, Boveri in the land field, as well as Brown, Boveri, Mannheim, will also be associated with this collaboration and development. Parsons Marine will, in future, offer their customers marine steam turbines of either Pametrada design, or those arising from this collaboration.

Copper Output Going Up

The Kennecott Copper Corporation recently announced that it is increasing operations at its Western Mines in the United States from four to five days a week, representing an increase of about 64,000 short tons a year. This will restore about half the total cuts made earlier in the year and is symptomatic of a general feeling in world copper circles that output restriction has achieved its object of bringing production and consumption into line. Mr. Harry Oppenheimer, chairman of Nchanga Consolidated Copper Mines, in his annual statement to shareholders, as we reported last week, said that the balance seemed to have been restored in the copper market. At about the same time, the vice-president of the Chilean Copper Department said that Chile's 1958 copper production was fully sold.

Apart from the general economic outlook, however, there are still a number of uncertainties to be resolved. Perhaps the most important of these is the future of United States Government stockpiling. The Minerals Bill provides for a stockpile of 150,000 short tons at market prices up to $27\frac{1}{2}$ cents per lb and at the end of July the United States custom smelter price reached this level partly on account of the strength of overseas markets and partly on hopes that the Bill would become law. There is, however, a strong body of opinion which considers that the Bill, which also provides subsidies for lead, zinc and five other metals, is unlikely to be passed in this Session of Congress.

The London Metal Exchange price has remained steady at a little over £200 per ton, to which it recovered gradually from the low point of £160 per ton last February. In the interim period there were several rises which proved short lived, but there would now seem to be reasonable grounds for anticipating stability or possibly a slow rise over the next few months.

The Human Element

Treatment for Shock

The Confederation of Shipbuilding and Engineering Unions have taken to heart the signs of falling industrial activity. They fear unemployment will have reached 750,000 by the end of the year, and this fear overshadowed proceedings at their annual conference. The maintenance of full employment was, according to several of the delegates, " the responsibility of the State." But large-scale redundancy cannot be avoided by legislation and its local character was thought to make a national agreement on procedure and compensation difficult to implement. Two resolutions, one by the AEU calling for a sharing out of work to avoid dismissals and another, by the TGWU, accepting the need for mobility of labour, were withdrawn. The uncertainty which now prevails in the engineering industry was fully reflected in the confused state of the views put forward.

On wages there was general agreement on a militant policy. The AEU's resolution, supported by the Boilermakers, the ETU, and other unions, declared that if the cost of living rises, so must wages rise. " We will oppose all attempts to impose a wage freeze which would reduce our members' standard of living." The resolution pledges " full support for any action which may be considered necessary " to realise the 6 per cent wage claim. But even in wages there is a growing realisation that falling order books are a greater threat than employers' avariciousness. It was clear throughout that the end of the labour shortage has had its shock impact but, equally, that much more thinking has to be done before union policy becomes adjusted to the new conditions.

Choppy in the Docks

Trouble is expected to follow the publication of the Court of Inquiry's report into the dock wage dispute. The uncompromising attitude of both parties does not suggest easy acceptance of the recommendations, whatever they may be. During the two-day inquiry, conducted under Lord Cameron's chairmanship, the Court were told that the dockers demanded an increase of 18½ per cent on the present daily rate. The port employers say that the present shipping slump makes any increase out of the question, because they cannot afford it.

A special meeting of the Transport and General Workers' Union will be held within a few days of publication to discuss the report. Eighty thousand of the 100,000 dockers involved in the dispute belong to the TGWU, and it is likely therefore that the other unions concerned will follow the big union's lead. The Court's award has been announced as 7*s.* 6*d* a week. There is, therefore, a possibility of a national dock strike if the TGWU find the award too low, or if the employers refuse to accept it. This, unfortunately, is the course likely to be adopted by each of them.

Margin of Uncertainty

Margins of uncertainty, so wide as to be positively frightening, continue to characterise the calculable effects of radiation on the world's population. A detailed report by the Scientific Committee of the United Nations, summarising current scientific and medical knowledge, concludes that " radioactive contamination of the environment resulting from explosions of nuclear weapons constitutes a growing increment to world-wide radiation levels. This involves new and largely unknown hazards to present and future populations; these hazards, by their very nature, are beyond the control of the exposed persons."

Ignorance is greatest on the possible effects on man of intermittent small doses or of low levels of continuous irradiation. Knowledge in this area is most urgently needed and the lack of it has been " of the greatest concern " to the committee. There are at present no practical methods of preventing the entry of radioisotopes into the human body once they have been released into the environment, states the report, and the greatest possible danger exists therefore in the continued explosion of nuclear weapons for test purposes. Radiation doses from radioactive waste disposal and accidents involving dispersion of radioactivity are at present negligible, but in the future " they might become appreciable." This is the most serious warning yet given to mankind of the dangers to posterity inherent in further development of nuclear sources of energy.

Putting on the Brake

The dismissal of 600 men by Vauxhall Motors after their annual holiday has led to a nervous expectancy of more dismissals elsewhere in the industry. The reasons given by Vauxhall suggest that falling export demand, due to seasonal factors in some markets and to import or credit restrictions in others, must have a deep impact on manufacturers' schedules. The major cuts need not, however, come until October or later. Other manufacturers have resumed full-time working after their own holidays and say that they are " fairly confident " that they will be able to maintain their high level of output " during the next few months."

Current trends suggest that confidence cannot, in fact, be very high. A seasonal dip in home demand—which has been the main prop of the industry's recovery from last year's minimum—is already being reflected in lower secondhand car prices. The American market, which has been absorbing nearly twice as many cars this year as last, is also expected to contract. The commodity price slump is beginning to have its effect on demand from New Zealand, South Africa and Australia. An overall fall of one-third in the level of output would not be surprising, and it might be exceeded.

More local trouble among vehicle body workers has broken out in Birmingham. Two hundred members of the Sheet Metal Workers' Society employed by Mulliners stopped work following the publication of a notice for four night workers to move from No. 2 to No. 1 factory. This, the management made clear, was the result of unbalance in production created by the sheet metal workers' own go-slow policy (since last week-end output was cut by one-third). Twelve hundred workers were idle and some 3,000 men at Standard's factories were on short time. There are no bodies for the TR3 sports cars (90 per cent of the 420 produced a week go to the United States), for Standard Companions and for light vans. The management are willing to negotiate but the men have, so far, remained obdurate.

Copper in Tension

Hard words are being spoken concerning the belligerent attitude taken by the Nkana branch of the European Union in opposition to economy proposals made by Rhokana Corporation. Since negotiations broke down last month over the implementation of the 38 " residual " jobs involved in the company's proposals, the union have refused to resume normal negotiations. They now threaten a complete ban on overtime. This, Rhokana say, would have effects similar to those of a strike, and it is clearly their intention to make a stand. They point out that the recognition agreement with the union clearly states that employees shall not have the right to refuse overtime if (among other things) such overtime is necessary for " the maintenance of shifts on continuous operations." Many of the 38 jobs in dispute—an example is changing scraper blades—require quite unskilled labour but the unions are demanding that skilled artisans, at the appropriate higher rates of pay, should be employed.

The copper industry's position remains delicate and any conflict would seriously damage the Rhodesian firm's ability to hold their own in world markets. The management of Rhokana have expressed their willingness to resume negotiations, but intend to suspend—they have the right to sack—any man who breaks his contract in this way.

Vindicated

The charge made in a report by a Committee of Public Accounts that the consulting engineer in charge of the construction of the Jodrell Bank radio-telescope acted unilaterally in changing the design, thereby increasing the cost by £240,000, has been wholly withdrawn. In their latest report the committee state that some of the evidence which formed the basis of their previous criticism was " gravely inaccurate and misleading." They find instead that there was " the fullest collaboration on scientific and technical matters between the consultants and the university professor." The report records that an additional £130,000 has now been paid to the university, making with previous contributions £560,000. The balance at present still outstanding will have to be found by the university from other sources.

In a Plain Words published last year (25 August, 1957, page 226), ENGINEERING welcomed the activities of the Committee of Public Accounts " in probing into cases of wasteful or careless expenditure," but added " it would seem to be a matter of elementary justice to allow the individuals or firms likely to be implicated to have their say before a report is published."

Declassified

At a forthcoming talk on the B.B.C. Third Programme (Monday, 25 August, at 8 p.m.) Mr. John Marsh, director of the Industrial Welfare Society, will discuss the social value of a man's job and the importance of this to his wife. A survey quoted recently by the B.B.C. indicated that in Britain 80 per cent of the adult population can say without hesitation to which class they belong. In the United States people find it much more difficult and there is little, if any, distinction in the off-duty appearance of the man employed on the shop floor or his office comrade.

Mr. Marsh will tell listeners that white-collar workers before the last war had a prestige in the community " out of all proportion to their usefulness." Their salaries and working conditions were much better than those of shop-floor workers, who were treated casually, employed by the hour, and given little security. The war has changed this almost beyond recognition and many office workers now envy the privileges and earnings of their fellows on the shop floor. Yet the word " salary " or the description " monthly staff " still have their prestige value, and a " wage " has a distinctively non-U ring about it.

The attitude of wives to husbands' jobs is greatly affected by the social standing that goes with it, particularly in mixed communities (increasingly a trend). " To the wife," John Marsh says, " her husband's job has social value in the eyes of her friends." He argues strongly that much more has to be done to bring the working conditions of shop-floor workers into line with that of office workers. Evidence from America suggests that it is an inescapable consequence of a rise in living standards; it could be a prerequisite.

Metals and Materials

IGNITION OF FIREDAMP BY STATIONARY METAL PARTICLES AND FRICTIONAL SPARKS

By F. P. Bowden, C.B.E., F.R.S.
and R. D. Lewis, PH.D.*

Methane-air mixtures may readily be ignited by small stationary metal particles heated in the gas, the most easily ignitable mixture containing approximately 6·8 per cent of methane. The minimum size of metal particle which is effective depends upon the nature of the metal: under the conditions of the experiments described, the order (in decreasing size of particle) was thorium, cerium, zirconium, titanium, magnesium, aluminium. This order runs parallel with the increasing heats of combustion of the metals and suggests that the amount of heat liberated by the burning particle is the important factor. With metals such as magnesium and aluminium, which have high heats of combustion, ignition of firedamp is obtained with particles as small as c.1 microgram.

Frictional experiments with rubbing metals show that the physical hot spots developed on the metal surfaces do not, under these conditions, cause ignition. If, however, small fragments of the frictionally heated metal are detached from the surface they burn, reach a high temperature, and ignite the gas. The mechanical properties and the "brittle" nature of the metals are, therefore, of primary importance. Zirconium and "pyrophor" are effective in causing ignition in this manner.

Some simple experiments have been made to investigate the mechanism of ignition of firedamp by metal particles which are produced by frictional heating and other means. The ignition of methane-air mixtures has been troubling the mining industry for at least 200 years, and interesting reviews of this have been given by Wynne (1952) and Titman (1955–56). Before the introduction of the miners' lamp by Humphrey Davey (*c.* 1818), pits which were too dangerous to be lit by candles were illuminated by a steel mill worked by a boy. The steel mill invented by Carlisle Spedding (1696–1755) consisted of a flint pressing on a rotating steel wheel so that it produced a shower of luminous sparks. The first explosion for which the steel mill was held responsible was at Wallsend colliery (Atkinson and Atkinson, 1886; Forster 1897–9), although a number of previous explosions may have been due to this cause.

Early laboratory experiments on frictional ignition were described in a collection of Volta's letters published in 1777. The subject has, since 1923, been extensively studied by the Safety in Mines Research Establishment. The work of this department has shown experimentally that coal cutter picks readily ignite firedamp if they strike siliceous strata (Burgess and Wheeler, 1929, 1931, 1933) or iron pyrites (Alsop and Wheeler, 1938–39). Similar experiments with coal cutters and sandstones are described by Beyling (1932).

The general problem of the development of local hot spots between impacting and rubbing solids has been discussed by Bowden and Tabor (1950) and Bowden and Yoffe (1952). It is shown that, in general, the temperature rise is limited by the melting point of the solid. If, however, the solid can be readily oxidised, and if this oxidation is a highly exothermic process (e.g., the oxidation of magnesium) the hot spot temperature may be very high indeed and is not limited by the melting point of the solid (Bowden and Thomas, 1954). Ignition of methane-air mixtures by friction between two iron or steel surfaces has been obtained (Robinson, 1939; Schultze-Rhonhof and Weichsel, 1950) although it does not occur easily. During recent years, attention has been focused on the ignition hazard inherent in light alloys. With aluminium based alloys, for example, a thermite reaction can be obtained on impacting or rubbing with rusty steel or iron and this can cause an explosion. This hazard has been studied in several investigations (Schultze-Rhonhof and Weichsel, 1950; Stern and Ford, 1944; Warrington, 1942; Titman, 1954; Titman and Wynn, 1954).

* Laboratory for the Physics and Chemistry of Solids, Department of Physics, Cambridge.

IGNITION BY STATIONARY HOT SPOTS

Since the problem of ignition by moving sparks is complicated by factors such as the velocity of the spark and its associated envelope of gas, a study was first made of the ignition by stationary hot spots. This may be accomplished by the use of small particles of easily ignitable materials with a high heat of oxidation.

The experiments were carried out in a rectangular brass chamber, 6 in by 6 in by 8 in, fitted with large Perspex windows. This could be evacuated and filled with gas mixtures of varying composition. It was sealed with a large cork which could be blown out by the explosion. A nichrome tape which could be heated by the passage of a current was mounted in the centre of the chamber.

Small particles of pyrophoric metals were obtained by filing the massive material with a coarse file and using the most regularly shaped pieces. These were weighed on a torsion balance, which reads accurately to a few micrograms, and were placed on the tape using a pointed glass rod. The tape was then heated by a constant current so that it attained a final steady temperature of 1,100° C, as measured with an optical pyrometer.

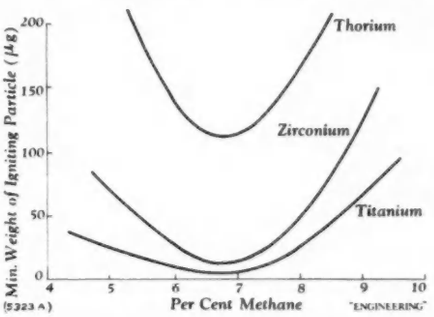


Fig. 1 The minimum weights of stationary particles of thorium, zirconium, and titanium necessary to ignite a mixture of air and methane varies with the mixture strength. The particles are initially at 1,100° C.

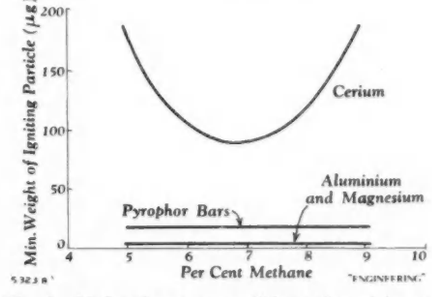


Fig. 2 Under the same conditions, the minimum weights of cerium particles producing ignition also vary; but 18 micrograms of pyrophor will ignite all gas compositions used and the estimated curve for magnesium and aluminium shows similar behaviour.

This temperature was below the ignition temperature of the most easily ignitable gas mixture so that the tape itself would not cause ignition. The following materials were used as hot spot producers—zirconium, titanium, thorium, cerium, magnesium, aluminium, beryllium, carbon, platinum and iron. Only the first six ignited the gas. Particles from "pyrophor" bars also ignited the gas. "Pyrophor" is a heterogeneous mixture of metals, containing 38 per cent cerium and total rare earth content of 73 per cent. It is commercially available and is used as the "flint" in cigarette lighters.

Zirconium and titanium particles.—Zirconium and titanium gave minimum weights for ignition which were reproducible. The results are shown graphically in Fig. 1 where the minimum weights for ignition are plotted against the percentage methane. It is seen that the most easily ignitable gas mixture contains approximately 6·8 per cent methane in each case.

Thorium Particles.—The results for burning particles of thorium showed more scatter than for zirconium and titanium, the curve shown in Fig. 1 represents a 90 per cent probability of ignition. In a few of the experiments, the particles glowed red, due to slow combustion, and did not burn to white heat: these were ignored. In this case also it is seen that the most ignitable mixture contains about 6·8 per cent methane.

Cerium and Pyrophor Particles.—Cerium particles gave a very good demarcation between ignition and non-ignition (Fig. 2). The most ignitable mixture again had an approximately 6·8 per cent methane content. Pyrophor particles, however, are equally effective over a large gas composition range. From Fig. 2 it is seen that 18 micrograms of the pyrophor will ignite all gas compositions used, the particles on ignition break up and "shooting stars" appear which are similar to those obtained from a cigarette lighter. Andreev and Rabinovitch (1950) also found that combustion accompanied by dispersal of hot particles (a criterion of rapid combustion) facilitates ignition.

Magnesium and Aluminium Particles.—Particles of these metals were remarkably effective in causing ignition, the minimum weights required being far below the sensitivity of the torsion balance used. Particles of an estimated weight less than 1 microgram were effective. The estimated curve is shown in Fig. 2.

Beryllium, Carbon, Spongy Platinum, Platinum Black and Iron Particles.—The above materials will not ignite methane-air mixtures under these conditions. Beryllium, carbon and iron glow red, while the platinum remains unchanged. The latter was used in an attempt to obtain catalytic action.

The results are summarised in the Table below.

Minimum Weight of Particle which Causes Ignition at 6·8 per cent Methane

Metal	Minimum weight (microgram)	Heat of combustion (kcal/g)
Aluminium	1	7·2
Magnesium	1	6·0
Titanium	4	4·5
Zirconium	6	1·96
Pyrophor bars ..	18	—
Cerium	85	1·68
Thorium	108	1·43

It is seen that the minimum effective weights decreased in the order: thorium, cerium, zirconium, titanium, and magnesium and aluminium. This is the same order in which their heats of combustion per unit weight increase. The temperature reached by the burning particles is

Continuing Metals and Materials

very high, intense white light is emitted and the temperature may be greater than 2,000° C.

The above experiments lead to the simple physical conclusion that the important factor under these conditions is the amount of heat energy liberated by the burning particles. It should be noted that tiny particles of aluminium and magnesium (which have high heats of oxidation) are very effective indeed in igniting the methane-air mixtures.

Small particles of explosive material such as lead azide were not effective in igniting the gas, probably because their time of burning was too short.

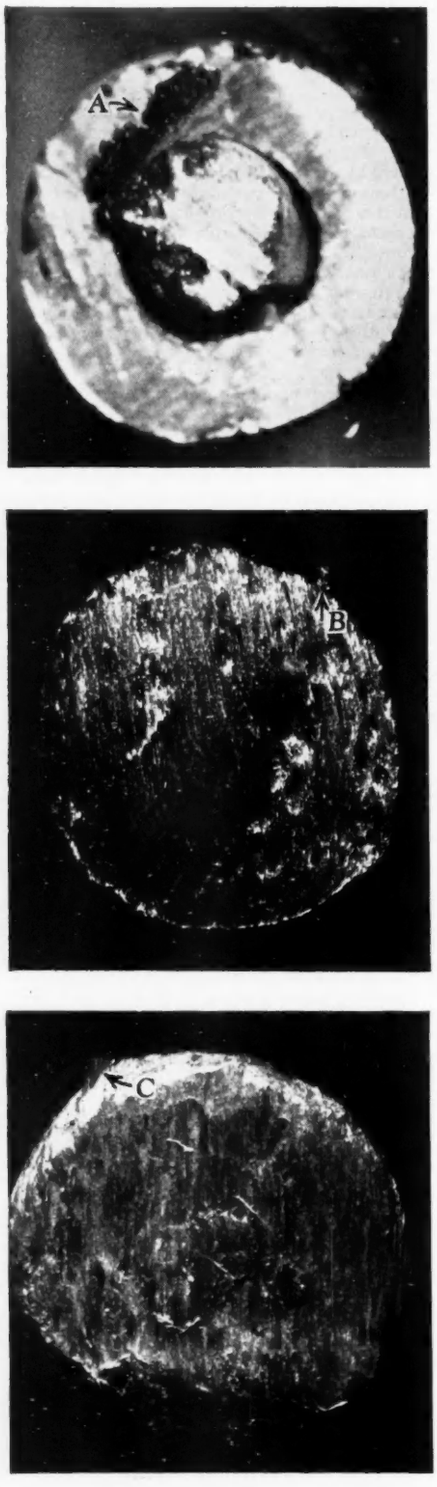


Fig. 3 Photomicrographs of the surfaces of cylinders of metal that have been rubbed against a wheel to produce sparks. The size of the metal fragment detached varies, being largest for pyrophor (A) and noticeably smaller for zirconium (B) and titanium (C).

IGNITION BY SLIDING FRICTION

The effect of hot spots generated by sliding friction on the ignition of firedamp is complicated by several factors. The hot spots formed on the moving surface will be less effective than similar stationary hot spots because of the diminished time of contact of any one small volume of the gas with the hot spot. Also gas in the vicinity of the hot spot is in a state of turbulence and this will increase the time lag for ignition.

In the experiments to be described below, normal physical hot spots on the moving surface were unlikely to cause ignition since the thermal conductivity of the surface is high and the heat capacity of the wheel large, so that any hot spot formed will have a very short life. Bowden and Thomas (1954) have shown that physical hot spots produced on solid surfaces by friction have a life-time of a few milliseconds or less. Also the maximum temperature attained by a physical hot spot is limited by the melting point of the material on which it is formed. Since firedamp will not ignite at 1,100° C, the hot spot temperature must be above this. The only metal used with a higher melting point was steel, and since the gas was turbulent and the hot spot moving, ignition by physical hot spots was improbable.

If, however, a small fragment of the frictionally heated metal is detached from the surface it may continue to burn and reach a very much higher temperature. If sufficient heat is liberated by its exothermic oxidation (e.g., zirconium and pyrophor bars) it may reach a temperature well over 2,000° C and may ignite the gas. Also, if the metal is very brittle (e.g., pyrophor), a concentrated stream of sparks is obtained and the local concentration of heat energy may be sufficient to ignite the gas.

The experimental apparatus consisted essentially of a steel wheel (10 cm diameter) which could be rotated at different speeds. The end of a small cylinder of metal (*c.* 0·25 cm diameter) could be pressed against the wheel under a constant load. As before, this was enclosed in a sealed chamber which could be evacuated and filled with methane-air mixtures. In using the apparatus the steel wheel was rubbed against the metal until it had a surface coating of the metal before readings were taken. In this way the readings were effectively those obtained by rubbing the metal against a wheel of the same material. This surface layer was removed between each set of experiments. The loads used varied from 500 to 1,500 g and the speeds from 200 to 1,000 cm per sec. There was no simple relation between these factors and ignition except that ignition was more readily obtained at the higher loads and speeds.

The following metals were used: magnesium, aluminium, 50/50 magnesium-aluminium alloys, 70/30 magnesium-aluminium alloys, steel, titanium, zirconium, pyrophor bars. Magnesium, aluminium and their alloys give no sparks and did not ignite the gas. A few small flying sparks were obtained with titanium (VDH 200) but not sufficient to ignite the gas. With zirconium (VDH 232) and pyrophor bars (VDH 216) copious sparks were obtained and ignition of the methane-air occurred. The pyrophor was more effective than the zirconium.

Surface photomicrographs of pyrophor, zirconium and titanium after rubbing are shown in the three parts of Fig. 3. It is seen that, in the case of the pyrophor bar, a large piece of metal (A, in Fig. 3), some 0·25 cm long, is about to be detached from the main body. The dark patches around the circumference are sloping surfaces where pieces of the metal have been torn away. In comparison with the pyrophor bars, the particle being broken from zirconium (B, in Fig. 3) is very small and that on the titanium is smaller still (C in Fig. 3). This difference from pyrophor is explained by the inhomogeneous nature of the latter.

The particles of metal which were abraded from the rubbing surfaces and projected into the gas were captured on a gelatine film and examined microscopically. It was found that with the effective metals, such as zirconium and pyrophor, numerous small metal particles were detached. For zirconium and for pyrophor the larger particles were about 0·3 mm diameter (200 microgram). With titanium, ignitions were not obtained and the detached particles were smaller; these particles, however, did burn on leaving the surface. With the other non-effective metals—magnesium, aluminium and alloys—no flying particles could be detected. The rubbing metal was plastically deformed and smeared over a sliding surface.

It is clear that ignition is brought about by the flying particles and not by the rubbing surface itself. In this frictional ignition the "brittleness" and the mechanical properties of the solids are of primary importance, since this determines whether particles will be detached or not and influences their size. The method of disintegration and of burning of the particle can also be important. It is noted that with a heterogeneous mixture like pyrophor the metal particles do not burn as a whole, but disintegrate into a number of widely dispersed burning sparks. This material is more effective in causing ignition over a wide range of gas composition.

It is interesting to note that with zirconium the minimum size of the flying particle which can cause ignition is appreciably greater than that of the stationary particle. This is probably due to the shorter time of contact with the gas and the greater thermal losses.

Some small-scale experiments have also been made on impacting metals. It is much more difficult to obtain ignition under impact than under friction. This is due partly to the fact that the impacting temperatures are in general not so high as the rubbing temperatures but even more to the fact that the metal is plastically deformed under impact rather than fragmented, so that particles are less readily detached.

We thank the Ministry of Fuel and Power for a grant (R.D.L.) and the Safety in Mines Research Establishment for helpful collaboration.

References

Allsop, G. A. and Wheeler, R. V. (1938–39). *Trans. Inst. Min. Engrs.*, **96,** 310.

Andreev, K. K. and Rabinovitch, M. A. (1950). *Zhu. Fiz. Khim.* **24,** p. 650.

Atkinson, W. N. and Atkinson, J. B. (1896). "Explosions in Coal and Mines." London: Longmans, Green.

Beyling, C. (1932). *Z. Berg.-Hutt.-u. Salinew.* **80,** 363.

Bowden, F. P. and Tabor, D. (1950). "Friction and Lubrication of Solids." Revised edition 1954 (Oxford University Press).

Bowden, F. P. and Yoffe, A. D. (1952). *The Solids* (Cambridge University Press).

Bowden, F. P. and Thomas, P. H. (1954). *Proc. Roy. Soc.* **A223,** 29.

Burgess, M. J. and Wheeler, R. V. (1929). Safety in Mines Research Board Paper No. 54.

Burgess, M. J. and Wheeler, R. V. (1931). Safety in Mines Research Board Paper No. 70.

Burgess, M. J. and Wheeler, R. V. (1933). Safety in Mines Research Board Paper No. 81.

Forster, T. E. (1897–8). *Trans. Inst. Min. Engrs.*, **15,** 78, cited by Burgess and Wheeler (1929).

Knight, H. A. (1943). Metals and Alloys, **17,** (5), 960–966.

Robinson, H. (1939). Safety in Mines Research Establishment Report (Unpublished).

Schultze-Rhonhof, H. and Weichsel, L. (1950). *Mitt. Westfalischen Berggewerkschaftskasse* (2).

Stern, A. C. and Ford, C. B. (1944). Iron Age, **153** (25), 64–70.

Titman, H. (1954). Safety in Mines Research Establishment Research Report No. 90.

Design

POST OFFICE LETTER SORTER

Production of the 20 electronic letter-sorting machines for the Post Office is now well under way at the works of the Thrissell Engineering Company Limited, Bristol, and the first machine has already been delivered. As the accompanying illustration shows, the developed machine is a fine-looking piece of equipment, capable of arousing a sense of pride in its operator. The design has been modified considerably from that of the prototype machine described in this journal last year (ENGRG., 31 May '57, p. 694). The machine can be transported as a whole, or readily broken down into three major assemblies 5 ft long by 2 ft 6 in deep by 6 ft high. Jacking trolley wheel bogies can be fitted.

Whereas with conventional hand sorting methods it is customary to sort into 48 racks, with the letter-sorting machine letters are directed automatically to any one of 144 stacking boxes. The operator sits comfortably on a chair and by operating a keyboard, comprising 12 left-hand and 12 right-hand keys, he codes the letters as they are presented to him in one of 144 two-digit codes. These codes have to be memorised—but the Post Office have found that, after a short training period, the task presents no difficulty to the ordinary post-office sorter. As may be seen, each letter is presented twice to the operator: he reads the address in the upper window, and keys the code when the letter falls to the second window. Experience has shown this "second chance" presentation speeds up the operation and increases the coder's accuracy. The keyboard is provided with a "cancel" key, enabling the operator to change his mind after he has coded and redirect the letter into a common "cancel" box. Another single key routes "peculiar" letters to a special box.

The machine is capable of receiving letters at a rate of over 6,000 per hour. Obviously, it is impossible to read letters at this speed and the average operator will work at about half the machine's available capacity. The limiting factor is the rate at which a man can read an address. There is no synchronisation by the operator; he can press the keys at any instant he desires and the machine will subsequently take control and accept the letter at machine rhythm.

Operation of the machine is as follows. Letters are stacked on to a feed conveyor which is automatically started and stopped by a photo-electric eye level device. Further piles of letters can be added while the machine is running. A full conveyor stack will last 30 minutes (at normal reading speed) before refilling becomes necessary.

The letter pick-up device is a suction mechanism which automatically picks up individual items of mail. A letter-bending mechanism prevents the feeding of two items at one time. The picking-up process is visible to the operator in a mirror. The feed mechanism presents the letter to the viewing window so that it moves slowly in a horizontal path into vision and is then transferred rapidly out of vision when read. The time available for the reading operation is entirely under the operator's control and has no time relationship to the machine rhythm. When the operator has keyed, the letter is immediately transferred and the next letter is instantly visible.

Both the letter presentation and the keyboard operation take place entirely at any random time chosen by the operator. The letter, however, can only be received by the machine at a rhythmic time. It is therefore necessary to despatch the leeter from the lower viewing window into a synchronising timing device.

At the instant the letter is despatched, the previously "stored" code is electronically translated and, simultaneously, selective mechanisms are set to ensure that the letter is correctly routed to its appropriate box.

The letters are conveyed through the machine by a series of rubber-tyred idler wheels sprung against rubber driven rolls. At every alternate roller station there is a switching arrangement which automatically stops the machine should a letter "jam." Throw-off devices take all pressure off the conveyor system to permit easy extraction of any letter when desired.

The selecting mechanisms consist of memory units which, at exactly the correct time, mechanically trigger diverter blades which route the letters, firstly to the correct row and finally to their destined box.

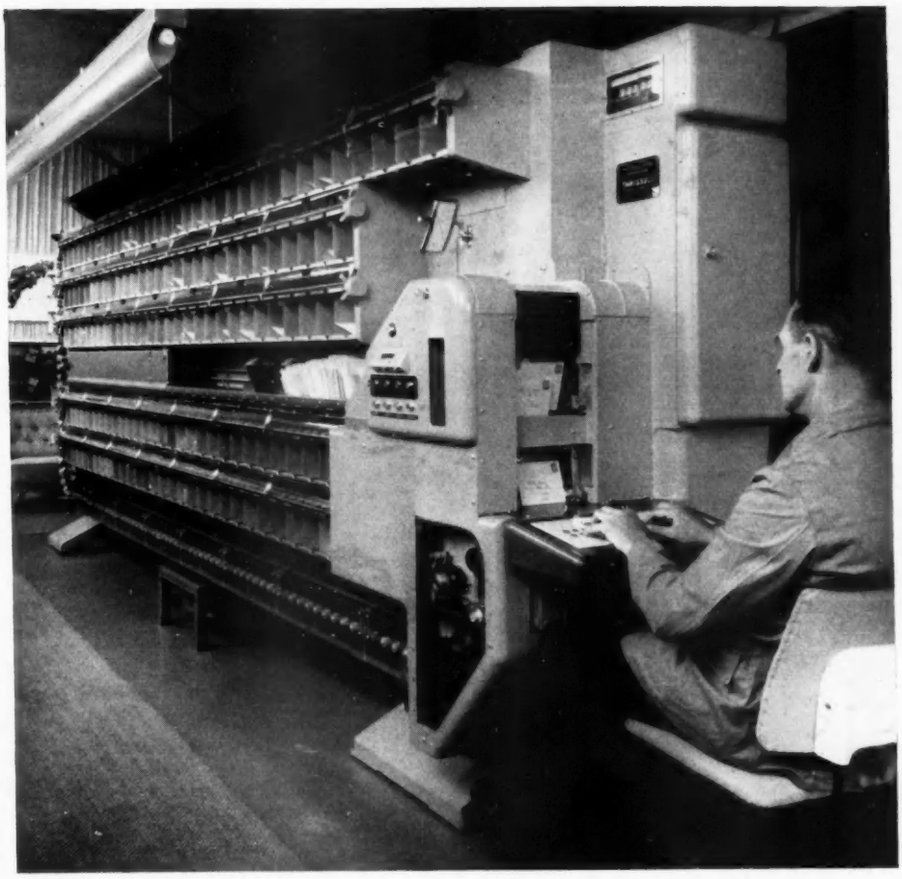
A letter too thick or too stiff for the conveyor system is rejected by a device in the presentation unit. Should this occur, or should a letter jam in the conveyor, an indicator on an alarm panel shows the operator where the stoppage is.

The complex electronic control equipment has been designed and made by Electronic Instruments Limited, Richmond. The prototype letter-sorting machine designed and built by the Post Office engineers used an electro-mechanical switching control system and some 400 valves. The redesigned equipment incorporates a system which is basically an electronic switch control, with no repetitive mechanical contacts and only 273 valves, mainly of the cold-cathode type.

The purpose of the electronic control equipment is to receive the code which the operator sets into the machine, and to operate the correct diverter when the letter is approaching the box to which it is to be delivered.

There may be several letters in transit in the machine at any one time, and so several codes may have to be stored at one time. This is done by having a code store for each physical position of the letter, and transferring the code from one store to another as the letter progresses from one physical stage to the next.

When the operator presses the keys, two sequences of events take place:—1. One of 12 first-stage cold-cathode storage tubes, each connected to one of the left-hand keys, is fired. Similarly, one right-hand cold storage tube is fired. The code is then contained in one left-hand and one right-hand first stage store. 2. A single-revolution clutch (S.R.C.) is electrically operated, and the clutch starts to rotate, opening a trap below the viewing window and allowing the letter in it to drop into one of two waiting gates; then opening the trap between the upper and lower viewing windows, and allowing a new letter to drop into the lower viewing window. As the S.R.C. revolves, it causes two timing pulses to be originated in sequence. This is done by a magnet on the periphery of each of two wheels attached to the clutch shaft, each passing a pick-up coil. The first, or "A," pulse causes a second set of 12



The letter-sorting machine is capable of receiving letters at the rate of over 6,000 per hour (but, owing to the operator's limitations, actually deals with about half this number), and automatically directs them to any one of 144 stacking boxes.

Continuing Metals and Materials

Titman, H. (1955–56). *Trans. Inst. Min. Engrs.* London) **115,** p. 535.

Titman, H. and Wynn, A. H. A. (1954). Safety in Mines Research Establishment Research Report No. 95.

Votla, A. (1777). Lettre del Sig. Votla sull aria inflammable nativa della paludi, Milan, cited by Burgess & Wheeler (1929).

Warrington, H. G. (1942). Messrs. High Duty Alloys Laboratory Report, 2445.

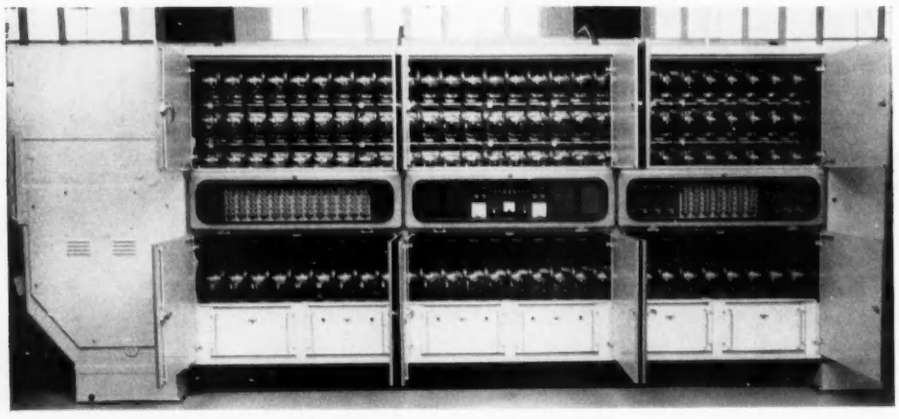
Wynn (1952). Safety in Mines Research Establishment Research Report No. 42.

Continuing **Design**

left-hand and 12 right-hand cold cathode stores connected to the first stages in cascade, to be momentarily extinguished, and thus cleared of any previous code. It then causes the code stored in one left-hand and one right-hand first stage stores to be transferred to the appropriate second stage stores. The second, or " B " pulse causes the first stage stores momentarily to be extinguished, thus clearing them of the code the operator had keyed in. The S.R.C. stops at the end of its revolution.

Until the operator keys again, there is a quiescent state with:—(1) a letter waiting in one of the waiting gates with the code appropriate to it stored in a pair of second stage stores, and (2) a new letter in the lower viewing window with the first-stage stores cleared to receive the new code when the operator keys it in.

When the operator presses the keys appropriate to the code of the new letter, the S.R.C. revolves again, causing further A and B pulses, allowing the new letter to drop into the other empty waiting gate, and allowing a third letter to fall into the lower viewing window. The " A " pulse, before clearing the second-stage stores, transfers the code in them (for the original letter) into the appropriate pair of third-stage cold cathode stores, of which there are again twelve left-hand and twelve right-hand connected in cascade to the second-stage stores. The cleared second-stage stores then receive the code for the second letter from the first-stage stores, and retain this code. The S.R.C. again continues to the end of its revolution causing a " B " pulse on the way, and clearing the first-stage stores again.



Back of the machine, showing the pin-wheel " memories " which operate the horizontal and vertical diverters routing the letters into their destined stack in response to the coded instruction.

Again there is a quiescent stage with:—(1) the original letter in its waiting gate with its code stored in a pair of third stage stores, (2) the second letter in the other waiting gate with its code in a pair of second stage stores, and (3) the first stage stores cleared, and a third letter in the lower viewing window waiting to be keyed in by the operator. The original letter is, however, only momentarily quiescent. It has progressed through all the stages under the operator's immediate control, and now waits to be accepted by the machine conveyor and pin-wheel memory system which operates at a cyclic rhythm.

The waiting gate is necessary for two purposes:—(1) To allow the operator to cancel the code in a letter previously wrongly coded. In this position the code is held in the second-stage stores. (2) To allow a letter to be held until the machine, working at cyclic rhythm, is ready to accept it. In this position the code is held in the third stage stores.

For each of the four level diverters and the 144 box diverters, which deflect the letter from the main conveyor into the appropriate level, and then into the appropriate box, there is a pin wheel memory. This consists of a wheel driven continuously by the main machine motor, with pins, axially parallel to the wheel, loosely held on its periphery. Also attached to the wheel are a lever operated by a magnet coil, both of which are fixed, and do not rotate with the wheel, but are radially adjustable on an arm with the same centre as the wheel; and a bell-crank which, when depressed, operates the diverter associated with the pin wheel.

When current is passed through the magnet coil, it moves the end of the lever into the circular track traced out by the pins as the wheel rotates. An inclined plane on the tip of the lever then forces the loosely held pins axially out of their normal position to a new position where they protrude from the side of the wheel. As the wheel revolves, these pins, which have been " set," will depress the bell crank and operate the diverter. The time taken for the pin to travel from the position where it has been set to the position where it operates the diverter is the same as that taken by a letter in the conveyors moving from the waiting gate to the diverter.

In order that the diverter will operate once only each time the magnet coil is energised, it is essential to energise the coil only when a pin is passing the inclined plane on the lever arm. The magnetising coil current must therefore be of square waveform timed to commence when a pin is in a position to be set, and to finish when the pin is set. This is achieved by a machine-timed matrix energising pulse.

A continuously-running shaft, attached through gearing to the main motor shaft, is arranged so that it will complete one revolution in the time taken for a pin to pass the setting arm on the pin wheel memories. On the shaft are two wheels, each carrying a magnet, which causes a pulse in a pick-up coil placed near each wheel. The magnets are so placed that one pulse occurs when a pin is in a position to be set, and the other occurs at a sufficient time later for a pin to have been set. An electrical voltage of square waveform is evolved from these pulses, starting at the first pulse and finishing at the second. This square wave is fed to all the level diverter coils, and through each to a common connection of all the box diverter coils on that level. The remaining terminal on each box diverter is connected to the anode of a " matrix " valve.

The matrix consists of 144 cold cathode valves, each called a " matrix " valve. These valves are electrically arranged in a square of twelve rows of 12 valves each. Each valve has an " and " gate in its trigger circuit, each column has one side of these " and " gates, connected together, the remaining side's of the " and " gate's being connected together in each row. To each of the vertical columns is connected one of the twelve left-hand third stage stores, and to each of the rows is connected one of the right-hand third stage stores. Thus, only that matrix valve which has both column right-hand third stage store and row left-hand third stage store fired, will be in a condition to fire.

As explained above, the anode of each matrix valve is connected to one terminal of a box pin-wheel memory magnet coil. If the matrix valve is fired when the square waveform is applied to its anode through the diverter coils, the pin-wheel magnet will operate.

Considering again the letter in the waiting gate with its code in a pair of third stage stores. The next matrix energising pulse immediately following the transfer of the code from the second to the third stage stores will (1) cause the trap below the waiting gate to open; feeding the letter into the main conveyor, (2) cause the code for this letter to be transferred from the third-stage stores to the appropriate matrix valve, firing it, and setting a pin in the appropriate level and box pin-wheel memories, and (3) cause the third-stage stores to be extinguished momentarily, clearing them so that they are ready to receive the next code, transferred from the pair of second stage stores holding the code of the letter held in the other waiting gate.

The original letter is now in the machine conveyor. When it approaches the level to which it is to be diverted, the pin in the appropriate memory wheel, set as the letter was released from the waiting gate, operates the level diverter, and the letter is deflected into the level conveyor. Similarly, the appropriate box diverter is operated as the letter approaches it, deflecting the letter into the box, where it will remain until the boxes are manually cleared. The pins in the memory wheels return to normal immediately after operating the diverters.

If an operator realises that he has wrongly coded a letter, he presses the " Cancel " key removing the code stored in the second stage stores while the letter is in the waiting gate, and codes an auxiliary second stage store which has its own third stage and matrix valves. The code progresses normally through this auxiliary system, and the letter is directed to a special " Cancel " box. If the operator is not able for one reason or another to assign a code to a letter, he presses a key on his keyboard marked " Transport." This fires an auxiliary first stage store, which has its own second and third stage stores, and matrix valve. The code progresses normally through this auxiliary system and the letter is directed to a special " Transport " box.

When the operator has coded all the available mail, he presses a button marked " Stop—Rundown." This releases the letter in the waiting gate and after a time sufficient for the letter to travel to the furthest box in the machine, automatically stops the main motor.

All the matrix valve anodes are taken separately to the control board. This consists of a fixed housing with 680 sockets into which fits a jumper panel with 680 plugs. The plugs may be cross-connected in any manner by removable leads. Thus any matrix anode can be connected to any diverter coil in the manner most convenient for a particular sorting operation. The jumper panel may be removed and replaced by another panel in a few seconds to facilitate change of sorting routine. A connection on each panel ensures that the main motor will start only if the panel used is the correct one for the labels which are showing above the sorting boxes. If the traffic to a particular destination is sufficiently heavy to demand the use of more than one sorting box, it can be arranged on the control board that letters to that destination will be routed to each of up to twelve boxes in turn.

A photo-electric counting system counts the letters passing through the machine, as they go along the main conveyor. The count is displayed on a tell-tale positioned beside the keyboard.

If an operator sees two letters in sequence to the same destination, he may code the second letter before the S.R.C. has finished its revolution started by the first letter. The second code will be held in the first stage stores, and cause a further revolution of the S.R.C. immediately it comes to the end of its travel. Thus the operator can momentarily increase his coding speed beyond 110 letters per minute.

PASSENGER FLOW IN SUBWAYS AND ON STAIRCASES

To provide guidance for the design of new underground stations, notably on their projected Victoria to Walthamstow extension, London Transport have been carrying out operational research on the flow of passengers in subways and on stairways. The main results of their studies (some of which may appear self-evident to regular " undergrounders ") are as follow:

(*a*) Above a minimum width of about 4 ft, the maximum flow in subways and on stairs is directly proportional to width. If the subway is narrower than this, multiples of shoulder widths become important. Under certain circumstances, a centre handrail dividing a passageway can reduce its capacity as a whole. (*b*) Stairways, movement on which is markedly slower than in subways, are likely to form bottlenecks in passenger movement systems. (*c*) When subways become more crowded there is an unconscious slowing down of movement, caused by a wish to avoid treading on the heels of the person in front. This effect results in the flow of passengers reaching a maximum beyond which increased crowding is accompanied by slowing down, so that no gain in flow is obtained. (*d*) Free passenger-flow speed in empty passageways was found to be 3·6 m.p.h., with speeds of 1·8 m.p.h. and 2·2 m.p.h. up and down stairs, respectively. Working figures have thus been obtained on which designers can base the dimensions of subways and stairs.

In the early stages of the investigations, observers visited a large number of subways and stairways, and timed passengers passing a specified point, in order to calculate the flow. It was found, however, that there were considerable variations in the results of a given spot, owing to the difficulty of deciding when the maximum flow for that particular point was taking place. Also, the flow of passengers in a subway was affected by events beyond the two ends of the section observed, which, it was found, could slow down the traffic and give false measurements. These difficulties were minmised as far as possible by taking a large number of measurements when a subway seemed to be fully loaded, and by using only the highest three readings, so as to obtain an average " maximum flow " for a given site.

As passageways became crowded, there seemep to be a gradual slowing down in speed, so that the flow past the point under observation was not necessarily increased by having a crowded subway. It seemed desirable, therefore, that the relationship between the speed and concentration of passengers, in conditions which would obviate interference from extraneous effects, should be investigated more closely. The co-operation of the headmaster of a boys' school in the south of England was obtained, and a controlled experiment was carried out with the help of some of his lads.

Two concentric rings of chestnut paling were held up by boys standing on an asphalt surface, to form a circular passageway initially 4 ft 3 in wide and 30 ft in internal diameter. Boys were fed into this passageway gradually, starting with a few walking round and ending with a dense crowd of more than 200 lads. Speed measurements were made at various concentrations for several passage widths and the shape of the speed-concentration curve was established from these measurements. The flow-concentration curve which resulted from this experiment is shown in the first of the three graphs reproduced on this page.

The behaviour of boys in these rather artificial circumstances was not exactly the same as that of passengers in actual transit, but the object of the experiment was to establish the shapes of the curves relating to variables rather than to obtain absolute values. Once the curves could be established, it was considered that it would be easier to understand what was happening in the London subways.

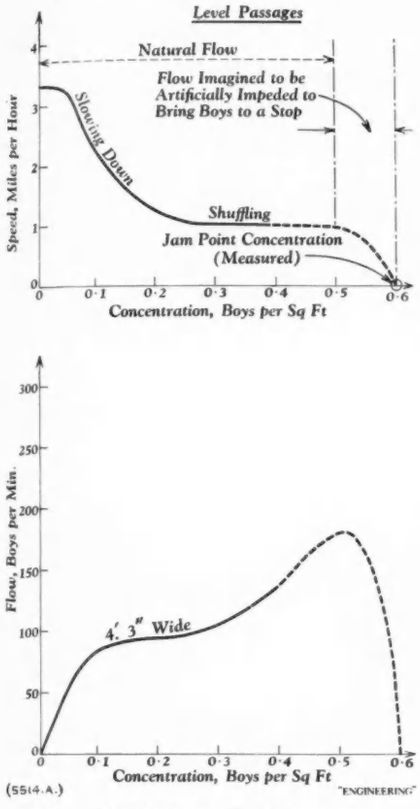
A simple and flexible method of measuring the relationship between speed and concentration was then evolved for use in the London subways themselves. Two observers with stop-watches stationed themselves in a subway at a measured distance apart. At a given signal both observers started their stop-watches and the up-stream observer joined the stream of passengers, walking with them at their own speed until he reached the other observer, when he stopped his watch. The down-stream observer counted all the passengers passing him between the time of starting his stop-watch and the other observer reaching him.

In this way, the total number of passengers originally in a measured area between the two observers was obtained (hence the concentration) and also the time of the movement (hence the speed). By carrying out these measurements in a number of subways at different concentrations, the general shape of the curves obtained with the boys was confirmed, and absolute values suitable to passengers in London were obtained.

Some of the results so obtained are given in the second and third of the three graphs illustrated. The second graph shows how the speed and flow concentration of London Underground passengers developed along level passages, and the third graph demonstrates, for comparison, the variations in speed and concentration which occurred during movements along stairways. In this graph, it will be noticed that the speeds on the stairways were based on the movement up the line of the stairs.

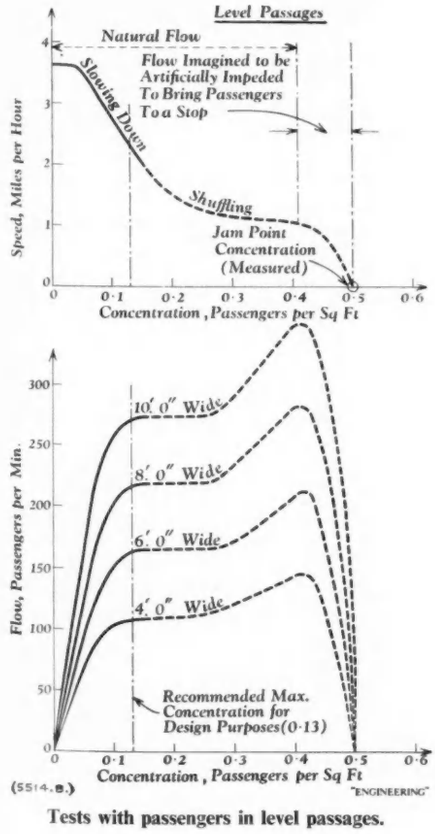
In summary, the suggested maximum flow for design purposes is 27, 19 and 21 persons per ft width per min. for level subways, upward stairs and downward stairs, respectively; and the corresponding concentration of passengers per sq. ft, 0·13, 0·16 and 0·15. Prior to this study, the figures used by London Transport were 30 and 17 passengers per ft width per minute in passages and on stairways, repectively.

The investigators found no analogy between the flow of passengers in subways and the flow of fluids, either liquid or gaseous, in pipelines.

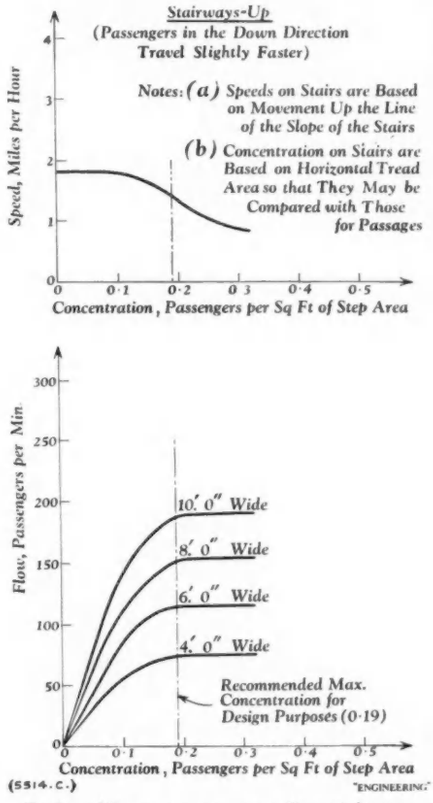


Tests with schoolboys in level passages.

Speed-flow-concentration curves obtained in operational research by London Transport Executive on passenger flow.



Tests with passengers in level passages.


Stairways-Up
(Passengers in the Down Direction Travel Slightly Faster)
Notes: (a) Speeds on Stairs are Based on Movement Up the Line of the Slope of the Stairs
(b) Concentration on Stairs are Based on Horizontal Tread Area so that They May be Compared with Those for Passages
Speed, Miles per Hour
Concentration, Passengers per Sq Ft of Step Area
Flow, Passengers per Min.
10′ 0″ Wide
8′ 0″ Wide
6′ 0″ Wide
4′ 0″ Wide
Recommended Max. Concentration for Design Purposes (0·19)
(5514.C.)
"ENGINEERING"

Tests with passengers ascending stairways.

Book Reviews

POLLUTION AND ITS PREVENTION

Sewage Treatment. By KARL IMHOFF and GORDON MASKEW FAIR. Second Edition. *John Wiley and Sons Incorporated*, 440 *Fourth Avenue, New York* 16, *N.Y., U.S.A.* (7·50 dol); and *Chapman and Hall Limited*, 37 *Essex Street, London, W.C.*2. (60*s.*)

The Treatment of Trade-Waste Waters and the Prevention of River Pollution. Edited by PETER C. G. ISAAC. *Public Health Engineering Section, Department of Civil Engineering, University of Durham, King's College, Newcastle-upon-Tyne*, 1, and *Contractors' Record Limited, Lennox House, Norfolk Street, London, W.C.*2. (45*s.*)

Symposium on Industrial Water and Industrial Waste Water. ASTM Special Technical Publication No. 207. *American Society for Testing Materials*, 1916 *Race Street, Philadelphia* 3, *Pennsylvania, U.S.A.* (non-members, 2 dol, members 1·30 dol)

Microbiology of Water and Sewage. By P. L. GAINEY and THOMAS H. LORD. *Longmans, Green and Company Limited*, 6 *and* 7 *Clifford Street, London, W.*1. (60*s.*)

Elements of Water Supply and Waste-Water Disposal. By GORDON MASKEW FAIR and JOHN CHARLES GEYER. *John Wiley and Sons Incorporated*, 440 *Fourth Avenue, New York* 16, *N.Y., U.S.A.* (9 dol); and *Chapman and Hall Limited*, 37 *Essex Street, London, W.C.*2. (72*s.*)

Until a few years ago there were few useful textbooks on the properties and treatment of polluting liquors; the spate of books now being published, of which the five under review are a representative sample, is a sign of the interest now being taken in this subject in all parts of the world.

The first, by Imhoff and Fair, has had a long ancestry, being derived ultimately from Imhoff's *Taschenbuch der Stadtenwässerung*, which was first published in 1907, is now in its sixteenth edition, and has during its history been translated into several European languages. The present work is widely acknowledged to be one of the best of its kind, particularly on the design of sewage treatment works; it is especially useful in including numerous worked examples of the calculations necessary—indeed one of its ancestors was published as *The Arithmetic of Sewage Treatment*. It is intended primarily for use in North America, but can be used equally well by the British designer if allowance is made for the different character of the sewage in the two countries and the fact that the quality of effluent required in Great Britain is likely to be a good deal higher than in many parts of America. Although the senior author is German, and has designed notable works in that country, most of the references are to American literature. It is true that there is some reference to British work in the chapter on the activated sludge process, though since the process was invented in England that is perhaps inevitable. This is an example (the fifth on this list is another) of the many books published recently in America which would be much improved if they took some account of advances made outside that country.

There have been lately some very successful and well-attended conferences and courses on the prevention of pollution. The book by Isaac contains the proceedings of one of the most ambitious of these courses, on the treatment of trade waste waters and the prevention of river pollution, held in the Department of Civil Engineering of King's College, Newcastle, during a fortnight in April, 1957. Twenty-two lectures, each by a different author, are reproduced in full, most of them with a useful list of references to literature, and followed by a summary of the discussions to which they gave rise. The course must have been very carefully organised, for the present volume covers nearly every aspect of its subject and can be used almost as though it were a textbook by a single author. It is divided into four sections, dealing with the chemical and biological effects of pollution in rivers, the legal position, and the discharge of industrial wastes to the sewers of local authorities; the analysis of effluents and the design of instruments used in their examination, measurement, and control; the various methods available for treating industrial wastes generally; and processes of treatment which have been adopted in particular industries. The last section, in which most of the lectures were by industrial chemists and engineers, is specially valuable and contains much information not easily available elsewhere.

The third in the list is also a record of the proceedings of a symposium on industrial waste waters, organised by the American Society for Testing Materials and held in California in 1956. It is a very slight publication of some 50 pages, many of them occupied with material of local interest only; it includes two short review papers on the desalting of sea water and the use of organic flocculating agents in treating industrial wastes.

Microbiology of Water and Sewage (to which a companion laboratory manual is also available) is intended as a text book for University students reading the wide variety of subjects included, in America, in the training of a public health engineer. The first third of the text contains a general account of the occurrence, classification, and physiology of bacteria, with chapters on algae and invertebrates, particularly those which are met with in the treatment of water and sewage. This is followed by two sections of about equal length on the bacteriology of water and the methods of treatment used at water works, and on the treatment of sewage. It is noticeable that while the bacteriological problem in water treatment—which consists for the most part in devising means of removing or killing as many bacteria as possible—has been satisfactorily solved, microbiological research has so far done very little to improve the methods by which sewage and similar liquids are purified. This is surprising, since at a sewage works microbiological processes, both aerobic and anaerobic, are carried out on a very large scale—certainly much larger than in any industry. It is true that the sewage has to be treated cheaply—one cannot, for example, afford to sterilise it and its bacterial flora is no doubt very mixed and changeable—but one would have expected the bacteriologist to have regarded this as a challenge and to have carried out much more research in this field than he has so far attempted.

Of the books here reviewed, the last, by Fair and Geyer, is the most important. It was written as a textbook for undergraduate students of public health engineering and is based on a larger work by the same authors (*Water Supply and Waste-Water Disposal*) which is generally regarded as indispensable to anybody engaged in research in this field. The authors, in their preface to the present work, set out the aim they had in mind when writing it—that is to encourage the study of the scientific principles underlying the treatment of water and waste waters and their application in the design of processes and plant. Sewage treatment works in particular have included a large element of empiricism in their design, and those familiar with Professor Fair's work during the past 30 years will appreciate how much he himself has done to replace this by calculation based on the physical, chemical, and biological behaviour of the liquors to be treated. Much remains to be done, but the importance of doing it is now generally agreed; the present book marks the stage so far reached. It is well illustrated by line diagrams, has a good index, contains numerous worked examples of calculations, and includes in an appendix a comprehsnive set of problems for solution by the student.

MODERN TIMES

A History of Technology. Volume IV: The Industrial Revolution. Edited by CHARLES SINGER, E. J. HOLMYARD, A. R. HALL and TREVOR I. WILLIAMS. *Oxford University Press, Amen House, Warwick Square, London, E.C.*4. (168*s.*)

This great enterprise is now nearing a conclusion as it enters the era of the industrial revolution with its fourth volume. Perhaps the most surprising discovery the reader without detailed knowledge of the subject will make is the age of the origins of much modern engineering. Hand tools for metal working have changed little since they took their present forms in the middle of the 17th century; wood-working tools are much older.

The period covered by this volume saw the development of machine tools, without which most of the other great inventions could never have been brought to fruition. Some form of lathe had been known for many years, although it did not become popular until the 16th century, and elaborate machines had been devised for the beautiful arts of instrument and clock-making, already well advanced in the 17th century. Ornamental turning was by then a gentlemanly hobby. The principles of many modern mechanisms had been developed earlier in the East or in Europe by Classical and Renaissance scientists, architects or military engineers; but it needed the social and economic changes which gave rise to the Industrial Revolution to make it worth while to introduce them in everyday practice.

The challenge of the new engineering of the steam age was met by the great dynasty of English machine-tool makers, from Wilkinson, whose boring machine made Watt's engine possible, to Nasmyth who invented the steam hammer, the shaper and the indexing milling machine. An interesting chart shows the employer-employee relationship by which, over 150 years, the knowledge and skill of each generation of these early production engineers were handed on. Only at the end of the period did the Americans begin to take the lead with the invention of the turret lathe and the development by Eli Whitney of the system of interchangeable-part mass production for the manufacture of muskets. Interchangeability was not, however, an original idea, having been conceived and put into practice by a French gunsmith named Le Blanc, whose methods impressed Thomas Jefferson; while mass production of pulley-blocks had been introduced into Portsmouth dockyard by Sir Samuel Bentham, with machines designed by the elder Brunel, in 1808.

Some myths are here disputed: Whitworth did not, it seems, invent the three-plate method of making a true plane surface—according to Nasmyth "a very old mechanical dodge." Apparently, also, Maudslay was not the inventor of the slide-rest or the lead screw, having been forestalled by Senot, a Frenchman, and Wilkinson, an American, at the end of the 18th century. As with so many other mechanical ideas, the lead screw and change-wheels had been devised by Leonardo da Vinci, but his drawing of them remained unpublished for four centuries.

This time gap between the intellectual conception of a mechanical idea and its later application, often by mechanics with little scientific know-

ledge, illustrates the change in attitude that was needed before it became respectable for men of science to participate directly in the "servile trades" as they were called; a change which had to await the social upheaval of the Industrial Revolution. This was the period in which the real groundwork of modern applied science was laid. The Royal Society had already sponsored "Histories of Nature, Arts or Works," which provided scientific descriptions of established crafts. An equally important systematising influence on contemporary technology was the work of the great French encyclopaedists. The work of individual men such as Christopher Wren in the 17th century and Count Rumford in the 18th, as well as the personal relationships of inventors like Watt with scientific leaders like Joseph Black and the employment of scientists as consultants in a number of industries, contributed both to the growth of a more scientific approach and to making applied science respectable.

What is interesting is the ease with which scientists of the period turned from one field to another: a lesson in the universality of the scientific approach which was revived in the activities of scientists in operational research during the Second World War. These developments were aided by the contemporary enthusiasm for the Messianic power of applied science as a liberator from the servitude of hard labour. It is not therefore surprising that the development of new sources of power was the most important feature of the age. The invention of pumping engines and steam blowers enabled coal and coke to take the place of charcoal and so led to the great changes that took place in the iron industry and to the invention of crucible steel by Huntsman. Although it was not until the 19th century that valid theories of heat and thermodynamics, founded on the work of Carnot, were formulated, the 18th century was a great era of experiment on machines of all kinds. Experiments were also made on the strength of materials, while mathematics and mechanics were already being applied to the construction of machines.

The period covered by this volume saw the founding of the professional societies and, in France before the end of the 18th century, of the first institutions for engineering education: the École Polytechnique and the specialist engineering schools. All that the United Kingdom could boast by 1840 was a Regius Professor of Engineering at Glasgow University.

Like its predecessors, this volume covers a wide field, from agriculture and fish preservation to sanitary engineering and dredging, and is copiously and fascinatingly illustrated. It raises many problems of the rise and fall of technological superiority in different times and places; for instance the causes of the reversal of the East-West flow of knowledge after the 15th century and how the craft mysteries of ancient technologies, which called for managerial supervision, were handed on. It is to be hoped that these matters will find a place in the fifth and final volume.

NEW BOOKS

Britannica Book of the Year 1958. *Encyclopaedia Britannica Limited, 11 Belgrave Road, London, S.W.1.* (105*s.*)

In March, 1957, the planners of the Britannica Book of the Year, 1958, had allotted space to the International Geophysical Year, but allowance for space exploration was at that time unforeseen. The search for illustrations to help in recording these events has led to the introduction of a page of cartoons as a sample of world reaction to the Russian achievement. New articles in this year's edition include Dead Sea scrolls and radiation, medical aspects of. Other new features include comment of the year, defence policy; European common market; Sahara, French; Soviet literature; world Scout jamboree; and a map showing world changes in population and food productivity.

Landing Gear Design. By H. G. CONWAY. *Chapman and Hall Limited, 37 Essex Street, London, W.C.2.* (56*s.*)

The author, formerly associated for many years with the development of retractable landing gear, has compiled this manual primarily for the young aeronautical engineer or student. He deals with the arrangement of landing gear, an elementary consideration of energy absorption, tyres, wheels and brakes, the general layout and detailed design of undercarriages, shock absorbers, the kinematics of retraction and the design of retracting mechanisms, the stressing of landing gear and a consideration of unorthodox types of landing gear. The work is profusely illustrated with diagrams and a number of photographs.

The History and Development of Light Cars. By C. F. CAUNTER. Ministry of Education: Science Museum. *Her Majesty's Stationery Office, York House, Kingsway, London, W.C.2.* (8*s.* 6*d.*)

The development of light cars has a long and complex history. This volume is perhaps the first comprehensive attempt to describe it, and presents the more important phases of evolution of the light car during the first 60 years of its commercial production and general use. Separate chapters are devoted to the main categories of light car so that the specialist forms of development may be followed more clearly from their inception, through their technical evolution and commercial production to their decline and replacement by more advanced forms. A bibliography is included and the book is well illustrated, some of the earlier line drawings being particularly attractive.

Universal Decimal Classification: B.S.1000B:1958. Trilingual (abridged) edition. *British Standards Institution, 2 Park Street, London, W.1.* (126*s.*)

The trilingual (abridged) edition of the UDC, which has been in preparation over the last three to four years, is the result of close collaboration by the editors and their colleagues in the four countries concerned—Belgium, France, Germany and the United Kingdom. It gives an outline of UDC schedules corresponding closely to B.S.1000A and other abridged editions. It is intended primarily for classifiers in all branches of documentation, library and information work who have to deal with technical and other literature in German, French and English. The editors believe that technical translators will also find this volume a valuable aid in their work.

An Introduction to the Dynamics of Airplanes. By NORMAN ABRAMSON. *The Ronald Press Company, 15 East 26th Street, New York 10, N.Y., U.S.A.* (4·50 *dol.*)

The purpose of this book is to introduce the basic principles and ideas of aeroplane dynamics problems suitable for senior college students who have had only a second or third year course in elementary dynamics and an introductory course in differential equations. Most of the problems encountered in aircraft and missile dynamics are principally vibration problems and the first third of the book therefore, is concerned with theory. The almost universal use of matrix algebra in the literature of aeroplane dynamics has demanded its inclusion in this text and a brief treatment is therefore given. There is also an introductory treatment of the flight stability of aircraft. The problems have been carefully selected to constitute amplifications or extensions of the text and should therefore be regarded as much a part of the theoretical treatment as the text itself. In addition to the topics already mentioned, the book also covers elementary wing flutter, aero-elasticity, landing impact, gust response and buffeting, effects of non-linearities, experimental and analogue methods.

Methods for Determining the Wave Drag of Non-Lifting Wing-Body Combinations. By L. M. SHEPPARD. Aeronautical Research Council Reports and Memoranda No. 3077. *Her Majesty's Stationery Office, York House, Kingsway, London, W.C.2.* (10*s.*)

The area rule, moment-of-area rule, and transfer-rule methods for estimating the wave drag of wing-body combinations are discussed. It is pointed out that the moment-of-area rule and the transfer rule are different forms of the area rule, and that the transfer rule expresses the interference wave drag in a simple form. The existing methods of wave-drag estimation are restricted to combinations with bodies having continuous surface slope and here an extension to combinations with bodies having discontinuous slope is given. This paper is concerned with the theoretical methods and their associated numerical techniques and no numerical results or particular applications are presented.

On the Shelf

By Frank H. Smith

Research Trends is a brochure put out from time to time by Cornell Aeronautical Laboratory, Buffalo 21, New York. Inevitably, since it is only of about eight pages, the "papers" are mere appetite-whetters, but the back page lists a number of very intriguing titles with the invitation to apply for copies—BUT there is an asterisk alongside all the most interesting ones. Those marked with an asterisk may be distributed only within the United States.

The July D.S.I.R. translated contents lists of Russian Translations looks a little more reasonable than usual. There seem to be less of the mating-habits-of-stunted-red-haired-field-mice and more of the roll-wear-in-strip-rolling-mills type of paper. All enquiries to Charles House, 5-11 Regent Street, London, S.W.1 (and that's the bit that goes down to St. James's Park if you happen to be walking from Piccadilly Circus).

"Available on request" makes nice reading and attached to something useful it's worth knowing about. The Aluminium Development Association of 33 Grosvenor Street, London, W.1 (MAYfair 7501) now has 1958 editions of its Directory of Members, List of Publications and List of Films, Film Strips and Wall Charts. Do you want to know where to get aluminium paste for paint, aluminium busbars, rolling slab, alloy castings, ingot, sheet? The first will tell you. Do you want a 20 minute film on fabrication of aluminum (sic) alloys, 35 minutes on pigs and progress, 58 minutes on the Man with a Thousand Hands? The third will tell you. The second list, I need not tell you, gives the publications of the A.D.A.—or had you guessed?

Cornmarket Press, 1 Lower James Street, London, W.1, now publish "The Directory of Opportunities for Qualified Men." I do not know how one qualifies to be a man but I know what they mean. It is like that certified and certificated business. The Directory starts with an editorial section with articles on "How Executives are Chosen"; "On being Interviewed"; "The Earning Power of Qualifications"; "Opportunities for Professional Men in Business"; a bit on emigration and a list of courses for executives and qualified men during 1958 under various headings (two in engineering). The second part of the book is a reference section, listing companies with recruitment schemes, organisations with emigration facilities, etc. At the end are a classified index giving information of firms in various fields and a "qualifications index" so that if you are a dredgemaster or an ink technologist or a sanitary superintendent you need not waste time but can turn immediately to p. 96, 58 or 97 respectively.

Odds fish. Fetch me a dictionary. Before me, I have the "Illustrated terminology of industrial trucks" issued in six languages by Fédération Européenne de la Manutention. It's that last word that has me foxed. Short interval for consultation . . . Manutention: 1, Management, administration. 2, Handling (of stores). I plump for the second. This F. E. de la M. has a British National Committee at 94-98 Petty France, London, S.W.1 (Passport Office Street), but they, apparently, do not sell this glossary which contains line drawings of hand trucks, power trucks, platform trucks—in fact almost every kind of materials-handling truck you can think of—with designations in German, English, Spanish, French, Italian, Swedish. If you want it, you must write to Compagnie Française d'Editions, 40, rue du Colisée, Paris 8e. But if you are prepared to corner the market you can get 3 per cent discount on 50-99 copies, 5 per cent on 100-299 copies and 10 per cent on 300 copies plus. But oh boy, what a gamble!

The 1958 edition of "Aviation Facts and Figures" published by American Aviation Publications, 1001 Vermont Avenue, N.W., Washington 5, D.C., costs 1·50 dol, and is a mine of aeronautical information.

Research and Development

HIGH SPEED PHOTOELASTICITY

Development and Application

By D. A. Senior, M.A., A.M.I.MECH.E.

The illustration, Fig. 1, shows a two-dimensional stress wave spreading into a sheet of xylonite from the point of impact of an air-gun pellet at the left-hand edge. A small hole has been drilled in the xylonite and the stress concentrations can be seen around the hole. The stress distribution is shown up by the photoelastic technique, and the movement of the wave, which travels at about 5,000 ft per sec in this material, has been arrested by the short-duration flash of an argon discharge tube.

The photograph was taken about 10 years ago during work[1] which yielded, so far as is known, the first pictures of stress waves in a solid material. Since then the new technique of high-speed photoelasticity has found application in various fields, principally in the study of the failure of materials under transient stresses. Useful information on brittle fracture has also been gained, and the interaction of reflected stress waves in bodies subjected to impact is now being made clear.

These and certain other applications will be discussed later in this article. As an introduction, the basic principles of photoelasticity will be very briefly described, with special reference to dynamic problems; some mention will also be made of the early attempts to study dynamic stresses.

BASIC PRINCIPLES

Sir David Brewster discovered, in 1816, the phenomenon of temporary double refraction—that is, certain substances, though they had no crystalline properties, behaved like doubly-refracting crystals when subjected to mechanical stress. Light falling on these substances was resolved into components polarised in two directions mutually at right angles, the two directions coinciding with the planes of principal stress. Moreover, the photoelastic substances, like the crystal, had two refractive indexes, one for each component. As a result the two components, which were initially in phase, emerged with a phase difference which depended on the distance travelled through the substance and on the values of the two refractive indexes.

The main significance of Brewster's discovery was that the changes in the refractive indexes were proportional to the magnitude of the principal stresses so long as the elastic limit was not exceeded. The effect is most conveniently expressed as the relative retardation between the two components, i.e., the number of wavelengths one component has gained on the other, or

$$R_t = C\,t\,(p - q),$$

where C is a constant, p and q are the principal stresses and t is the thickness of the specimen.

It was almost a century before this discovery was put to practical use—by Coker in this country and Mesnager in France. Their technique was to illuminate the stressed model with plane-polarised light, and to view the model from the other side through an analyser by means of which changes in the state of polarisation could be determined. Modern methods employ the same principle, but different materials of higher sensitivity and more convenient apparatus. For example, the Nicol prism is giving way in many applications to polarising filters employing dichroic crystals which selectively absorb one component. These filters can be had in relatively big sheets and have contributed much to recent advances in photoelastic technique, as larger fields of view are now possible with simpler optical arrangements. This is an important consideration in high-speed photoelasticity for the stress waves move at speeds up to 15,000 ft per sec, and can have travelled across the model and back again in 40 microseconds even with a relatively large model.

Polariser and analyser are set at right angles so that, in the absence of stress, no light emerges from the analyser. In the presence of stress it can be shown that, neglecting absorption losses, the intensity of the emergent light I is related to that of the incident light I_0 by the equation

$$I = I_0 \sin^2 2\theta \sin^2 \pi R_t,$$

where R_t is given by the equation already quoted and θ is the angle between the plane of polarisation of the incident light and the principal plane of stress. Thus the image of the model consists of alternate dark and light areas. It is evident from the formula that extinction occurs when the retardation R_t is an integral number of wavelengths and also when θ is zero or 90°. Thus extinction for a given wavelength occurred along lines of constant stress difference—the isochromatics—and along lines where the direction of the principal stresses lay at angles of 0° or 90° to the planes of the polariscope—the isoclinics.

Most photoelastic stress analysis—high speed or static—employs the isochromatic pattern, though the isoclinics are of value and a use of them in high-speed photoelasticity will be described later. When the isoclinics are not required they can be eliminated by the use of circularly-polarised light. This is produced and analysed-with the help of quarter-wave plates which introduce a quarter-wavelength retardation. The arrangement is shown in Fig. 2 and it can be shown that the intensity of the light leaving the analyser is given by the formula $I \sin^2 R_t$. The angle θ is no longer involved, so the isoclinics have disappeared.

The lines of complete extinction are termed fringes, and it can be shown from the formula already given that the principal stress difference changes from one fringe to the next by an amount $\lambda/C\,t$. The product of the principal stress difference and Ct/λ is called the fringe order at that point. The fringe order is in fact equal to the number of fringes which pass the point during application of the loads.

From the fringe order (which can also be determined by counting the number of fringes starting from a region of known stress difference) and the photoelastic sensitivity of the material, the stress difference can be deduced for any point in the model. For accurate analysis, the more sensitive materials are used, or compensation techniques are employed to determine fractions of a fringe. These employ a stressed specimen aligned with the principal stress direction in the model and so arranged that the light passes through specimen and model. It is evident that only an extremely complicated experimental arrangement would enable this to be done for transient stresses, but a method has been developed which goes some way toward the determination of fractional fringes, and which can be used in determining dynamic stresses. The method is described by D. Post[2] of the Naval Research Laboratory, Washington, D.C., U.S.A. It employs two partially silvered mirrors, one on each side of the specimen. The light rays are reflected to and fro, and traverse the model several times. By inclining the mirrors slightly, light which has traversed the model a given number of times can be isolated to give a fringe pattern which exhibits several times as many fringes as the conventional pattern.

Determination of the Sum of the Stresses.—There remains the problem of determining the sum of the principal stresses: the method so far described gives only the stress difference and the sum is needed if the individual stresses are to be calculated. One way out of the difficulty is to work from the boundary where the stress normal to the boundary is zero, so that the

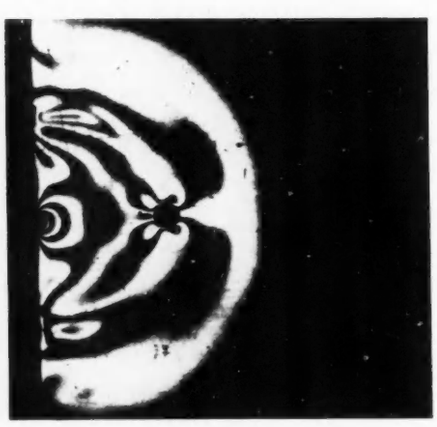


Fig. 1 Stress wave from impact of air-gun pellet spreading in sheet of xylonite. The photograph was taken by electronic flash, 48 microseconds after the initial impact of the pellet against the edge of the sheet.

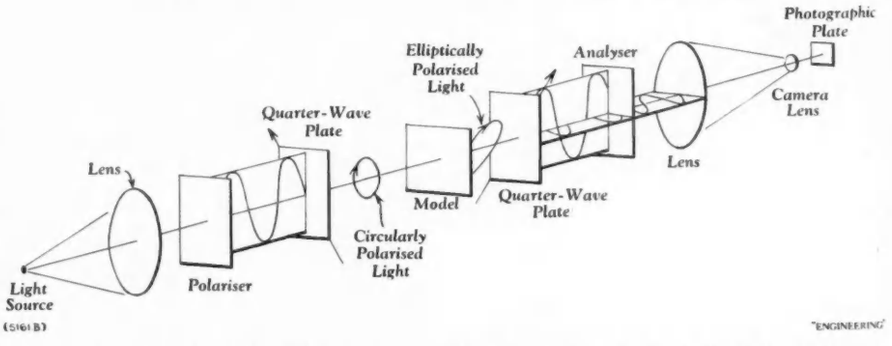


Fig. 2 The standard circular polariscope, as used in conventional ("static") photoelastic work and, with suitable light source or camera, in dynamic work. This yields a fringe pattern describing the difference between the principal stresses.

stress difference gives the stress parallel to the boundary directly. Laplace's equation then gives the principal stress sum at any point in the model. This involves a tedious integration if carried out mathematically but can be effected experimentally by the well-known soap-bubble method. Laplace's equation, however, describes the stresses in the body when all the forces are in equilibrium; it does not take account of stress inequalities associated with the acceleration of parts of the model—the essence of dynamic photoelasticity. It is to be remembered also that it is in dynamic problems that there is the greatest chance of important stresses occurring at points remote from the boundary. So the method of integration from known boundary conditions is of little use in dynamic work.

Another method of determining the sum of the principal stresses, the isopachic pattern as it is called, is to measure the increase in the thickness of the model. Coker achieved this, though the lateral strains are only of the order of one-millionth of an inch, and since his time many other methods, mechanical, electrical and optical, have been developed. All involve elaborate and expensive instruments, sensitive to vibration and temperature changes, and none has yet achieved the accuracy desired. If this is so in static work, the problems involved in applying the method to dynamic changes can well be imagined. Frocht used an optically flat model and an auxiliary optical flat placed close to it and deduced the lateral distortions from the changing interference pattern. Drouven and Post used a method suggested by Mesmer in which reflections from the two surfaces of thin models were used. Both methods have been successful but for dynamic work something better is needed.

A most promising development is the series interferometer of D. Post.[3] Basically it consists of three partially silvered mirrors. If these are parallel and light is incident on, say, the left-hand one, there are various optical paths as shown in Fig. 3, which is taken from Post's recent account of his work. When the optical distances d_1 and d_2 are nearly equal, the rays which traverse paths such as F and G interfere to form a fringe pattern which describes the difference in optical distance between adjacent mirrors at any point in the field. In addition, there exists a background due to paths such as H and K. Post shows that this background can be eliminated by employing an inclined mirror system and that, when the first mirror is inclined at an angle α and the second at an angle $\alpha/2$ to the third mirror, the fringe order N is related to the mirror separation by the equation

$$N\lambda = 2(d_2 - d_1)\cos\gamma,$$

where d_1 and d_2 are optical distances and γ is the angle of incidence. Thus, when the model is inserted between two mirrors and the spacing between the mirrors is adjusted for approximately equal optical paths, a fringe pattern is obtained which describes the thickness contour of the model, and thus the sum of principal stresses.

Post states that, when the interferometer is illuminated with collimated light at normal incidence to the mirror farthest from the source, the fringes appear to be localised in the first mirror and this surface becomes the object plane for observation.

In practice, two glass plates form the three mirrors, one being partially silvered on one face and the other on both faces, while peak fringe intensity is obtained by using certain calculated reflection/transmission coefficients. As the model is not initially optically flat, two fringe patterns are photographed one before and one after the application of load. In this way the non-uniformity of thickness of the model is cancelled out. White light is unsuitable for the present instrument as the media on both sides of the centre mirror have different light-dispersion characteristics, but highly monochromatic light is not required for good fringe definition. This is an advantage, particularly in dynamic work, as high-intensity sources are essential (the peak fringe intensity is only 14 per cent of the incident) and, as will be shown, it is

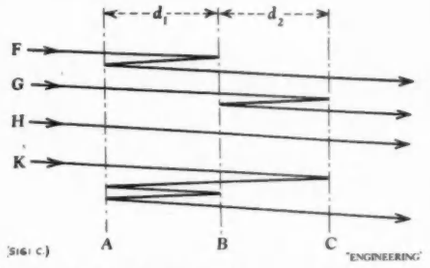


Fig. 3 Light paths in Post's series interferometer, which produces a fringe pattern describing the model thickness and thus the sum of the principal stresses.

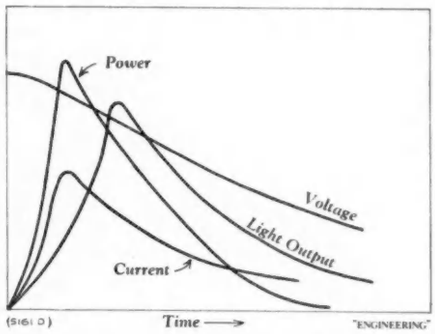


Fig. 4 Variation of current, voltage, power and light output for a typical flash-discharge tube. The time during which the light output is significant can be as short as a fraction of a microsecond.

difficult to make these monochromatic. Finally, the model must not be bi-refringent as the velocity of light through the model must not vary from one place to another. For this reason, two models are used; one is bi-refringent and provides the isochromatic or stress difference pattern; the other is non-bi-refringent and provides the isopachic or stress-sum pattern. From the two patterns, the individual stresses are derived.

MATERIAL SENSITIVITY

It is, of course, useless to count the fringes if the sensitivity of the material is unknown. This sensitivity is generally expressed as the fringe value for the material and is equal to $\lambda/2\,C$ where C is defined by the equations already given. Expressed another way, it is the change in shear stress $(p - q)/2$ required to produce one fringe in a model of unit thickness. It can readily be measured in static tests by stressing a specimen of the material, generally by bending it, but it is not sufficient to use the static value in dynamic measurement without further tests.

There might, for instance, be a time lag between the application of stress and the occurrence of the optical effect; or the sudden application of stress might give rise to a different fringe value, by virtue, for example, of the temperature rise. The fringe value of all photoelastic materials varies to some extent with temperature, and since the stresses are suddenly applied there will be a rise in temperature at the wave front where stresses are high. (In static work, the material has ample time to cool to the ambient temperature.) It can be shown that the rate of change of temperature with pressure in adiabatic compression is equal to $3\alpha\tau/\rho K_p$, where α is the coefficient of linear expansion, τ the absolute temperature, ρ the density and K_p the specific heat of the material at constant pressure. For the materials in common use the temperature rise works out at only 4° C for a 10,000 lb per sq. in change in pressure, the material being assumed to be compressed in all directions. The temperature effect should therefore be small.

The problem of measuring dynamic sensitivities was foreseen in 1939 by Findley[4] of the George Washington University, though at that time dynamic photoelasticity was virtually restricted to high-speed cine photography of stress patterns. Findley carried out experiments to determine the dynamic fringe values of various materials. His method was to apply sudden bending loads to a beam of the material. In pure bending, the stress pattern consists of a series of parallel lines and the movement of these lines was recorded on a moving film in a drum camera, a magnesium spark providing the light source.

The experiments suggested that the fringe value for Bakelite did not vary with the rate of loading up to the maximum rate involved (which was not specified), but that for celluloid the value dropped by about 16 per cent. Variation in the values of the modulus of elasticity could not be taken into account, so there was some uncertainty in the results. No further work on this fundamental parameter has come to the writer's notice; but it is to be expected that progress in high-speed photoelasticity will soon call for it.*

PHOTOGRAPHING RAPIDLY VARYING STRESSES

The earliest high-speed photoelastic records were probably those of Tuzi and Nisida (1928-36) who used continuously moving film to record stresses in a cantilever subjected to impact. The effective exposure time of 1/46,000 sec was sufficiently long, however, for a stress wave to travel almost three times the depth of the cantilever, so naturally no indication of stress propagation was to be expected.

High-speed cine photography has more recently been used to record, photoelastically, the rapid variations of stress in machine parts. The cameras used in this work are generally of the " rotating optic " type, in which the film moves continuously and the image is made to move nearly in synchronism with it by means of a rotating glass block. One of the earliest applications was in examining the changing stress pattern in a rail chair subjected to cyclical loading. Each picture, even with the camera running at full speed, corresponded with the static stress pattern. Again, there was no hint of stress propagation.

It seems to have been in 1951 that the first cine photographs showing evidence of stress propagation were obtained. Professor Riparelli, of Cornell University, used gelatine specimens in which the speed of stress propagation was relatively low. The specimens were suspended

* Since this was written, Clark has published measurements of dynamic stress-optical coefficients and elastic moduli for Columbia Resin 39. These both showed an increase of about 18 per cent when the loading time was decreased from 10^{-1} to 10^{-4} sec. (*Proc. Soc. Exp. Stress Analysis*, vol. 14, No. 1, 1957.)

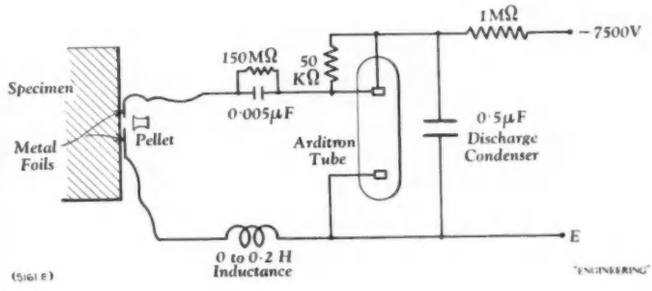


Fig. 5 Circuit arrangement for photographing high-speed stress waves in xylonite sheet. The pellet completes the circuit just before striking the plate, triggering the discharge of the condenser, and so producing a flash after a suitable delay period.

Continuing Research and Development

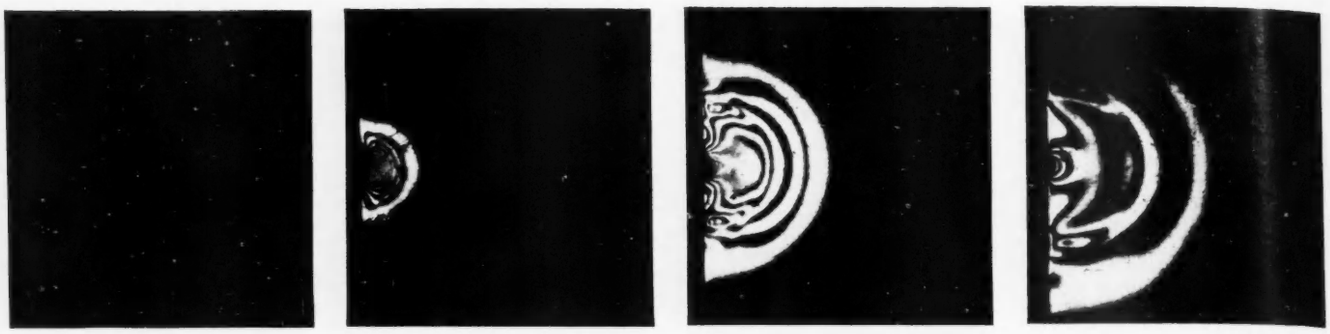


Fig. 6 Pellet striking the edge of a wide plate. A two-dimensional compressive stress wave travels in to the plate and is

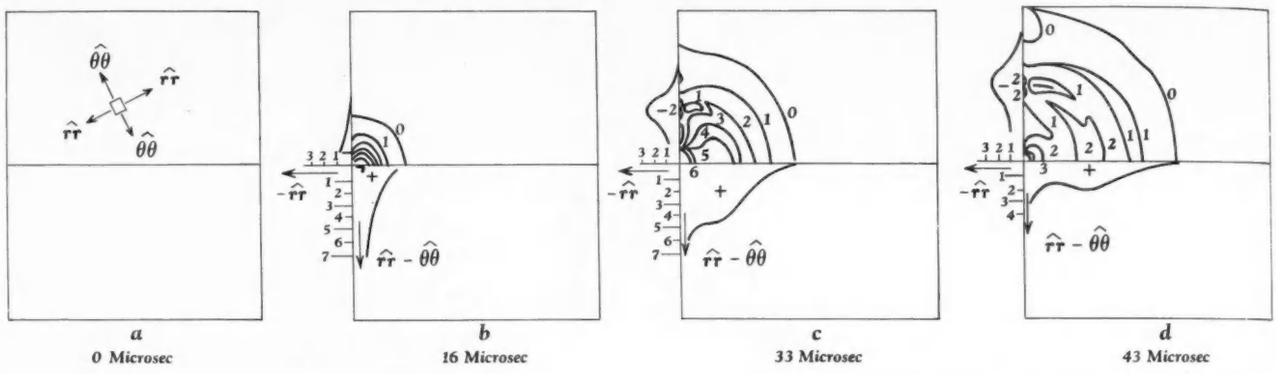


Fig. 7 Principal stress differences corresponding to the fringe

and struck at the bottom. Difficulties were encountered with creep and even rupture as the material was relatively weak mechanically. They could be overcome by floating the specimens in liquid; but when this was done the wave patterns were distorted. A satisfactory solution to the problem was finally found by Perkins,[5] also of Cornell University, who laid the specimens horizontally on a lucite plate and lubricated them with wave-set lotion. He reported that there appeared to be no frictional effects, and that there were no initial fringes and no restrictive boundary conditions.

The best results were obtained, however, with rubber specimens and a silicone car polish. The waves travelled at 150 ft per sec and so could be followed by a camera running at 5,000 frames per sec.

LIGHT SOURCES

Concurrently with the more recent of these developments, other methods were also being tried. Flash-discharge tubes were used as light sources and the first true stress-wave pictures were taken in 1946; one of them is reproduced in Fig. 1. Image-converter tubes were also used; these provide a high-speed shutter and enable cyclical stress variations to be viewed stroboscopically. Finally, the multiple-spark camera, devised by Cranz and Schardin some years previously, was used to study the propagation of cracks and stresses in brittle materials.

The work in 1946 employed an Arditron discharge tube developed by the Armament Research Department during the war and now available commercially. The tubes were originally wanted for the photography of bullets in flight and gave a flash of extremely short duration (about 1 microsecond). They were thus very suitable for photographing stress waves which moved at a speed of 5,000 ft per sec. There are now many flash-discharge tubes equally suitable, and characteristic curves for current, voltage, power and light output for a typical tube is given in Fig. 4. However, at the time the work was carried out, the Arditron had the most reliable triggering characteristics of all of them—an important consideration when a delay of 10 to 20 microseconds could lead to the loss of the picture.

The shortest duration flashes are obtained with the smallest condensers, charged (for a given energy) to the highest voltage. This requires the gas pressure to be high so as to give a high enough breakdown voltage, and makes the tubes hard to trigger. It does, however, help to shorten the flash duration, by reducing the mean free path of the ions and so allowing more rapid recombination or de-ionisation. The exact duration cannot be specified as the light intensity decays gradually and ceases to be important at a point which depends on the photographic materials used. For this reason it is desirable, whenever the amount of light permits, to use process plates in high-speed photoelastic work. These plates have a sudden cut-off, changing from zero to full exposure for a small change in light intensity. Thus the peak of the light/time curve can be used and the effective photographic duration of the flash reduced to as little as half a microsecond. Process plates possess a second advantage: they are sensitive only to wavelengths less than 5,000 Ångström units, and this helps to reduce chromatic effects which are aggravated by the high current densities required in the discharge tubes. These current densities give rise to a large number of wavelengths in the radiated light. This gives good colour rendering in normal photography but is a drawback when a monochromatic source is required. A third advantage of process plates is the sharpening of the fringes due to the high contrast quality of the emulsion.

FLASH PHOTOGRAPHS

The combination of process plates and glass components in the polariscope eliminates wavelengths outside the range 4,000 to 5,000 Å.U., the major part of the light output from the tube being in the region of 4,300 to 4,500 Å.U. The result is that chromatic effects and isoclinics are effectively eliminated and good fringe photographs can be obtained.

The arrangement of the flash tube, condenser and triggering circuit is shown in Fig. 5. In the Arditron, the triggering is achieved by raising the potential of the third electrode, which consists of a ring concentric with the rod cathode. This is done by means of a simple resistance/capacity/inductance circuit completed by the pellet which also imparts the impulsive stress to the specimen. The delay between the impact and the flash is varied by adjusting the value of the inductance.

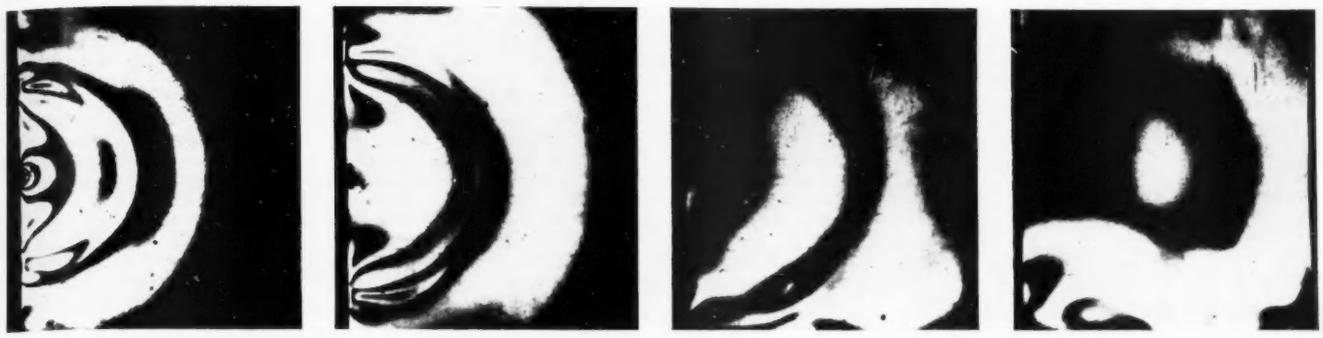
There is an inherent minimum delay in the circuit but this is counterbalanced by the fact that the trigger circuit is completed slightly before the pellet reaches the model, sparks jumping from the foils to the pellet when the separation is about 1 mm.

Fig. 6 shows the pressure waves produced by the impact of a 0·22 in bore lead pellet on the long edge of a xylonite plate measuring 6½ in by 4½ in by $\frac{3}{16}$ in thick. The pellet was travelling at about 450 ft per sec. The pressure wave appears to expand radially with uniform velocity. It is reflected at the far edge of the plate, and, at the edges, as tension waves which interact with the primary wave and with each other to produce a complicated pattern of stresses.

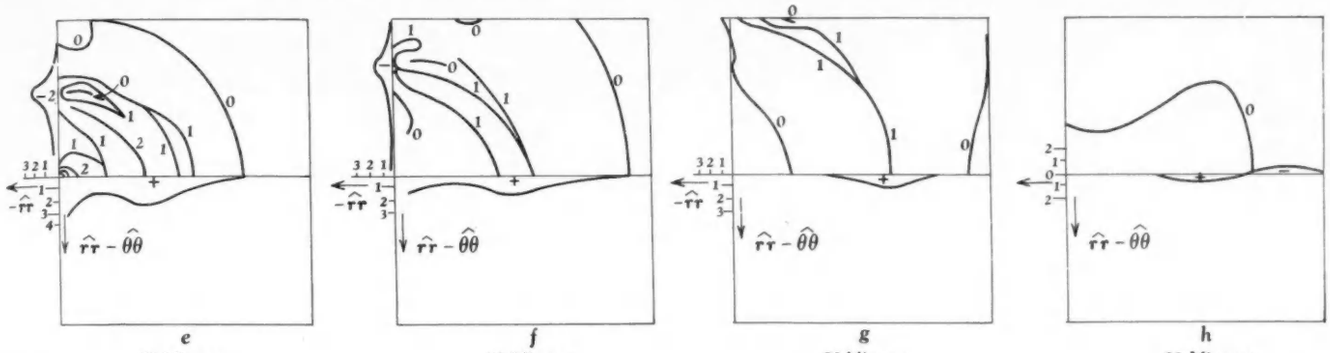
A feature of the pictures are the " closed loop " fringes which are formed near the edge of the specimen and travel outwards along with the wave. These are known as isotropic points and are believed to arise from the inter-action of compression and tension waves, the compression wave being that transmitted to the plate by the direct impact, and the tension waves being formed at the impact edge much as the tension of a taut string is increased by plucking it. The analysis of the pictures, carried out by Dr. A. A. Wells, is illustrated in Fig. 7. The fringes are sketched and the fringe order given. The shear stress along the centre line ($\widehat{rr}, -\widehat{\theta\theta}$), and the tension along the impact edge ($-\widehat{rr}$) are also given.

IMAGE CONVERTER TUBES

Another method of showing up stress propagation employs image converter tubes. These tubes were used by the Services Electronics



reflected at the boundaries, while tension waves travel outwards from the point of impact along the edge where impact takes place.



photographs in Fig. 6; the stresses are plotted as fringe orders.

Research Laboratory to give a very convincing display of transient stresses at the Physical Society Exhibition in 1951. The image converter contains a semi-transparent photo-cathode. An image of the photoelastic model is focused on this cathode by means of a lens, the model being illuminated by a continuous source. Within the tube, distribution of light on the cathode is converted into a corresponding distribution of emitted electrons. These are accelerated and focused magnetically on to a fluorescent screen where the image is reproduced. The tube is fitted with a control grid which cuts down the electron emission when a negative potential is applied exactly as in an ordinary thermionic valve. This blanks off the screen as though the tube contained an optical shutter. The difference is that the shutter can be operated at high speeds.

In the exhibit, the model consisted of a bar of C.R.39, a highly sensitive photoelastic material. The bar was arranged vertically, the lower end being connected to a magnetostrictive vibrator. The vibrator comprised, in essence, a nickel tube surrounded by a solenoid. The solenoid was energised at 20 kc/s and the vibrations generated a train of stress waves about 2 in in wavelength in the model. The waves were absorbed in felt pads at the upper end of the bar. The image converter grid was operated at frequencies around 20 kc/s. When the frequency exceeded that of the vibrator the stress pattern moved down the bar; for frequencies below that of the vibrator the stress pattern moved upwards.

MULTIPLE-SPARK CAMERA

The third method of recording the progress of transient stresses employs the multiple-spark camera of Cranz and Schardin. This camera, first described in 1929 and shown diagrammatically in Fig. 8, employs sparks in air as light sources and a bank of separate cameras each of which receives light from one spark only. This is achieved by means of the field lens, which focuses an image of each spark into the corresponding camera lens. When the spark occurs, the whole field appears to be illuminated to the appropriate camera, and against this background the subject, in this case the photoelastic stress pattern, appears. The cameras receive negligible light from other sparks so the pictures are independent of one another. The sparks are triggered in succession and a series of photographs is obtained in which the time intervals can be made as short as is desired.

It will be appreciated that this is an ideal tool for the study of any transient phenomenon which can be made to appear as a silhouette; so it is admirably suited to photoelastic work. Schardin himself in Germany and now in France, Kolsky and Christie and also Stanton in England, and Post in the United States, have all used this type of camera in studying photoelastic problems. Zandman in France has used a rotating multiple-spark gap in conjunction with a rotating drum to obtain the same effect, though at lower speeds (18,000 pictures per sec). Finally Schweiger, in Germany, has used a combination of photoelasticity and photoelectricity to measure dynamic stresses. This article will conclude with a description of some of the results these workers have obtained.

STRESS WAVES THEORY

Some important properties of stress waves will first be described. Stress waves, of which sound waves are an example, can be in one, two or three dimensions. They can be longitudinal, in which the particles of the material move along the line of propagation (compression or extension waves); transverse, when the particles move at right angles to the direction of propagation (shear waves); or flexural when, in the case of a plate, the particle movement is at right angles to the direction of propagation and to the plane of the plate. Here, only the first two types of wave are of interest.

Single-dimensional compression waves or waves of dilation move with a velocity given by the well known formula

$$C = \sqrt{\frac{E}{\rho}}$$

where E is Young's modulus for the material and ρ is the density. For two-dimensional dilation waves the velocity is given by

$$C_1 = \sqrt{\frac{E}{\rho(1-\nu^2)}}$$

where ν is Poisson's ratio for the material. In many of the materials used in photoelasticity $\nu = 0{\cdot}3$, so the velocity of two-dimensional waves is 5 per cent greater than that of waves in one dimension.

The other waves of interest are shear or transverse waves, also called waves of distortion. These have a velocity given by the equation

$$C_2 = \sqrt{\frac{G}{\rho}}$$

where G is the shear modulus. Since $G = E/2(1+\nu)$, it follows that

$$\frac{C_1}{C_2} = \sqrt{\frac{2}{1-\nu}}$$

so that, in xylonite and Perspex, the dilation waves move at about 1·7 times the speed of the distortion waves.

When stress waves of either type are reflected at a surface both types are, in general, produced. The angles are related by the velocities C_1 and C_2. If a plane dilation wave strikes a free boundary at an angle of incidence α, measured relative to the normal, then the reflected dilation wave also makes an angle α, while the distortion wave makes an angle β where $\sin\beta = \frac{C_2}{C_1}\sin\alpha$. These angles refer of course to the direction of propagation of the wave. The wave front lies at right angles to this direction.

The amplitudes of the reflected waves can also be deduced from the elastic constants of the material. (The derivation is given by Kolsky.) The relative amplitudes depend, of course, on the angle of incidence and they are plotted in Fig. 9. Similarly, an incident distortion wave is reflected as a distortion wave at an angle of reflection equal to the angle of incidence; a dilation wave is also produced at an angle γ

Continuing Research and Development

given by the equation $\sin \gamma = \frac{C_1}{C_2} \sin \alpha$. When $\sin \alpha$ exceeds C_2/C_1, total reflection occurs and the dilation wave is absent.

EXPERIMENTAL CONFIRMATION

Christie[6] used high-speed photoelastic methods to examine the truth of these statements which were only known previously from the theoretical standpoint. He used a multiple-spark camera and a circular polariscope to take sets of nine photographs, at time intervals varying from 5 to 50 microseconds, of the reflection of plane dilation stress waves at the edge of a Perspex sheet.

He also developed a method of indicating the fringe order. It will be remembered that, when monochromatic light is used in a circular polariscope, the transmitted light changes from extinction through full transmission to extinction again as the shear stress changes through a certain amount. The actual magnitude of the shear stress is therefore indicated by the number of times this occurs (the fringe order) as the load is increased gradually from zero. In dynamic work the fringes cannot be counted in this way and further information is required if the stress pattern is at all complicated.

This information can be gained by using white light. Since the effect depends on the wavelength of the light, destructive interference occurs with increasing fringe order, first for short wavelengths and then for successively longer ones. Thus the colour of the fringe, which is determined by the wavelengths that are left, permits the fringe order to be inferred; Christie succeeded in taking high-speed colour photographs sufficiently free from colour distortion to enable this to be achieved.

The pressure wave was generated by firing a length of " Cortex " detonating fuse which was laid along one edge of the Perspex model. The angle of this edge was chosen so that, as the detonation wave travelled down the fuse, dilation and distortion waves moved across the model to be reflected at a second edge forming the free boundary. This edge could be cut at any desired angle and in this way the reflection process could be studied. The width of the model was sufficient for the dilation (compression) wave to reach the boundary well ahead of the slower distortion (shear) wave which was also generated by the explosion. The photographs showed good agreement between experiment and the classical theory. The incident pulse, and the two reflected pulses, could be seen clearly, and some interesting results relating to reflections at grazing incidence were obtained.

DILATION WAVES

It had been shown by Roesler[7] that the boundary would react back on the incident pulse in such a way as to cause the principal stresses to turn through a small angle. Dilation waves were reflected at grazing incidence from a slit cut in the model, and the change of angle of the principal stresses was observed by the use of plane (not circularly) polarised light, the plane of polarisation lying at an angle to the slit. The system reveals the isoclinics, the lines of constant direction of the principal stress planes. No disturbance could be propagated in the material with a velocity faster than that of dilation waves, so the only part of the model which could be affected lay within a distance from the end of the slit equal to the distance moved by the dilation wave along the slot. Within the limiting circle the light intensity would therefore be expected to increase or decrease according to the direction of rotation of the stresses, and this effect was observed. By varying the plane of polarisation, the maximum effect was found to occur at 8°. This was somewhat low according to the theory which gave 11°, but as was pointed out, the value of 11° would be reached only after the pulse had travelled some distance along the edge and the dimensions of the model were limited.

As previously mentioned, one of the principal applications of high-speed photoelasticity is found in the study of mechanisms where materials are found to fail under transient stress. Kolsky and Christie[8,9] did pioneer work on the subject when they examined the fractures of glass and plastics subjected to shock loading from explosions and high-speed projectiles, relating the phenomena to the interaction of the various stress waves.

They point out that four factors distinguish dynamic from static failure: with short pressure pulses, any cracks which occur do not have time to spread before the stress has been removed as the pulse passes on ; stress waves move with a finite velocity, so a very short pulse occupies only part of the specimen at any one time, and fractures may form in one region quite independently of events elsewhere; reflection of waves at boundaries complicates the stress distribution, compression waves being reflected at free boundaries as waves of tension and vice versa, the reflections combining at certain points in the specimen and opposing each other at other points, so that large local stresses are being developed. Moreover, the elastic properties of substances vary tremendously with the rate of loading.

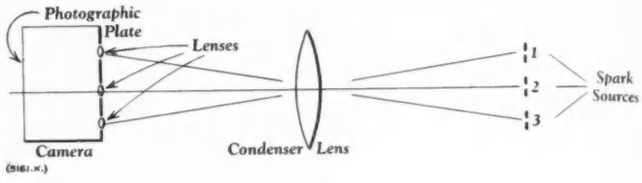


Fig. 8 Arrangement of Cranz-Schardin multiple-spark camera. The light from each spark enters one camera lens only. The sparks are triggered in succession to yield a series of independent silhouettes at any desired time interval.

Short pulses, only a few microseconds in duration, were produced by firing small charges of lead azide in contact with sheets of glass and Perspex. The fractures were compared with those produced by firing rifle bullets at the specimens. Here the pulse was very much longer, up to 100 microseconds, so that stress waves could travel several feet and cracks grow several inches during the application of stress. The final fracture patterns were quite different. The bullets produced radial cracks which ran the full length of the plate, while the explosions led to tiny fractures which seemed to have started separately and then joined together. The fractures produced by the bullets were similar to those produced statically, but the explosions led to something new.

In further experiments, " Munroe jets " were formed by means of hollow metal-lined explosive charges. These jets consist of a high-velocity stream of metal particles, their speed being about three times the maximum velocity of stress waves in Perspex. These experiments showed both types of fracture. Near the charge, the stress was applied for a short time and innumerable cracks appeared in regions of intense fracture surrounded by undamaged material; farther into the specimen the particles were moving more slowly, big cracks had time to form with consequent stress relief, and the static type of fracture occurred.

The interaction of direct and reflected waves was shown, again by means of explosive charges. As the material was weaker in tension than in compression, there came a time when the reflected tension wave exceeded the compression in the initial wave and caused failure some distance in from the free surface of the specimen opposite the charge. Then a large scab was thrown off in the form of a circular disc. If the specimen were restricted in area of cross-section, tension waves from sides and bottom would be expected to reinforce along lines running in diagonally from the bottom corners, and this effect was observed.

There were still phenomena which could not readily be explained by the simple theories of reflection. This was to be expected, since the reflection of compression waves as simple tension waves and vice versa only occurs when the wave meets the reflecting surface normally. With other angles the pattern is more complicated, as has been shown. One such phenomenon was the circular fracture concentric with the charge, and on the same side as the charge, which occurred only when the side remote from the charge was free to move.

The difference in the behaviour of materials, such as Perspex, when the rate of loading was increased was shown clearly by examining the specimens in a polariscope after they had been subjected to short or long pressure-pulses. When the pulse was long, creep had occurred and residual stresses existed in the specimens; but with rapid rates of loading the specimen contained fractured regions surrounded by regions where the stress was zero, typical of brittle failure.

A great deal can be deduced, then, from an examination of the final fractures; but a complete picture of the process can be built up only from measurements of the stresses themselves as they occur and as the material fails under their action.

Such measurements have been made by Christie and others using high-speed photoelasticity. Christie's camera was of the Cranz-Schardin type, already described, and he studied the propagation of cracks (mainly in glass) and stress waves (mainly in Perspex); in Perspex their velocity is lower than in glass. Pressure pulses were applied directly by detonating explosive charges in contact with one edge of the specimen. The stress patterns could be related to the theory of dilation and distortion waves, already outlined, and pictures were obtained in which the stress pattern and the crack formation could be observed together. The distortion waves could be seen more easily than the dilation waves as their photoelastic effect was greater.

Failure of the material was caused by various stress patterns. The tension wave reflected from the bottom of the plate (remote from the charge) could be observed as it caused fracture cracks to appear some way into the specimen. Again, the combination of two distortion waves was shown to produce cracks. These were the distortion wave which was produced directly by the explosion (in association with the compressive dilation wave) and the distortion wave produced by reflection of the dilation wave at the sides of the specimen. Finally, the compressive stress, on moving towards corners of the specimen, developed a tension tail as theory predicted. When the tensile strength of the material was exceeded, the corner flew off, taking with it the momentum of the compression wave trapped within it.

The cracks could be seen to form individually and then join up. The direction of the initial flaws was found to approximate to that of one of the principal stresses at the time, which suggested that the material (glass) was failing under tension rather than shear. Examination of the cracks in the material revealed narrow irregular bands where the glass had been powdered; this suggested that the visible cracks might be the result of a large number of separate microscopic cracks. Some of the cracks had mirror surfaces and these were identified as running cracks. After a few reflections the stress waves would be of relatively low intensity but cracks already formed could be extended though no new ones would appear.

To explore the time effect further, pressure pulses of chosen length and intensity were applied to the specimens in an ingenious way:

a steel bar was placed in contact with the specimen, being "wrung" in with grease. An explosive charge was fired in contact with the other end of the bar. The form of the pulse varied with the diameter of the bar and with the size of the charge, and consisted of a compressive "head" followed by a "tail" in which the pressure alternated. The method of connection of the bar and specimen ensured that only the compressive head of the pulse was transmitted to the specimen. To ensure identical conditions at the plate for the various sizes of bar, a small diameter connecting piece was employed between the bar and the plate. By adjustment of the diameter of the bar and the size of the charge, long or short pulses could be produced as desired. The pulse length with the $\frac{1}{4}$ in and 1 in diameter bars was 35 to 40 microseconds, while that with a $\frac{1}{4}$ in diameter bar was 15 microseconds. The longer pulse produced a stress distribution which differed completely from that due to explosive charges fired directly in contact with the specimen, while the 15 microsecond pulse gave an intermediate pattern.

The longer pulse gave rise to stress distributions in the plate similar to those with a static load. The isochromatic fringes—lines of constant shear stress—took the form of closed rings, corresponding to the pattern from a non-uniform static load on a small area. With a load uniformly distributed the fringes consist of circles passing through the extreme edges of the area; with short pulses the dilation and distortion waves soon separated and could be identified.

The fractures which resulted from the two pulse lengths were quite different. The characteristic powdered cracks arising from short-duration stresses have already been described. With the long-duration pulses there was no sudden rise of local stress due to reflections and the cracking resembled that due to a concentrated static load; that is large cracks started on each side of the point of pressure or occasionally a single crack would travel down the centre of the plate.

STRESS WAVE EFFECTS

The effect of a stress wave passing over an existing crack was also examined and showed some interesting features (the cracks in glass have a maximum velocity of about 4,500 ft per sec, while distortion waves travel at speeds of the order of 10,000 ft per sec; there was thus opportunity for the stress waves to repass any cracks which were formed, provided the duration of the pressure pulse was low enough). Schardin has shown stress waves originating at the point of fracture when a crack is being formed and there is, in any case, a stress concentration at the tip of a running crack. This is increased when a stress wave passes over the crack; intense local fracturing can occur and the crack may branch. As the branches spread, the stress is relieved and it is suggested by Christie that this might account for the changing appearance of the cracks at varying distances from their point of origin. While the stresses were high a large number of isolated cracks would join up to give the finely ground "powdered" appearance; later only the larger flaws would produce cracks, giving a rough surface; finally the stress would be sufficiently low for only the very largest flaws to become cracks, and this would give the mirror-like surface.

Schardin has done much work on the same problem and has secured striking pictures of the various kinds of fracture as they occur. He has also shown that the velocity of propagation of cracks in glass is a function of the density of the glass, varying from 7,000 ft per sec for quartz glass of low density to 2,500 ft per sec for heavy flint glasses. One technique which he has developed makes use of the crack itself to trigger the spark which photographs both the crack and its associated stress pattern. Bands of metal are evaporated *in vacuo* on the surface of the specimen and an electrical signal is derived from their change of resistance as the crack reaches them; this signal is used to trigger the spark. Other workers (Hudson and Greenfield) have used a number of such bands to determine the propagation velocity of cracks.

The most recent photoelastic work on brittle fracture to have come to the writer's notice is that published in 1957 by Wells and Post.[10] This work overcame two of the drawbacks of the photoelastic technique: firstly, that the stresses revealed are the mean averaged through the thickness of the plate and, as these are not entirely uniform, blurring of the fringe pattern can occur; and secondly that only shear stress is revealed, a serious limitation since it has been proved in one case at least that the material fails under tension in the direction of the greater principal stress.

Wells and Post employed the fringe multiplication method developed by Post to yield an adequate number of fringes with models of limited thickness (Columbia resin was used and the models were $\frac{1}{8}$ in thick). This avoided the blurring of the pattern which resulted with thicker models. The interferometer method of Post for determining the sum of the principal stresses was also used and sequences of photographs were taken with a multiple-spark camera. The combination of the three techniques enabled particular stresses to be determined at any point in the model at any required interval of time. In practice the intervals were 40 or 70×10^{-6} sec and the exposure time was about 10^{-6} sec.

The use of a sensitive material and fringe multiplication is in interesting contrast to the use of glass by earlier workers. But, in the recent work, the interest lay in the stress distribution around a single running crack where low fringe orders are often involved. The aim was to examine the stress distribution around a fracture propagated from one edge into a tensile specimen of limited width and so determine a static system of forces which would give the same stress distribution. An initial crack was made to a small depth; the specimen was then loaded until the crack began to run, the spark sequence being triggered by the rupture by the crack of a conductive line of paint applied to the specimen.

Wells and Post point out that this is the more usual case in practice though theoretical work (Yoffe, 1951) has been restricted to cracks which closed up at one end as they advanced at the other. In this case, the theory indicated that the dynamic and the equivalent static stress distributions would differ only negligibly. With a running crack, however, there was reason to think that differences would arise.

It was found, by comparing the dynamic stress distributions with simulated static ones, that although there was similarity in the immediate neighbourhood of the cracks, the presence of stress waves led to differences in the distribution at some distance from it. For example, the load on the unbroken ligament (i.e., the section of the specimen as yet unreached by the crack) fell off rather less than proportionally to stress travel but at two specimen widths away there was little diminution in load until the crack was well advanced, as would be expected from the finite rate of stress propagation. The average stress on the unbroken ligament increased, but only by 50 per cent, and this was clearly less than a constant load on the specimen would involve.

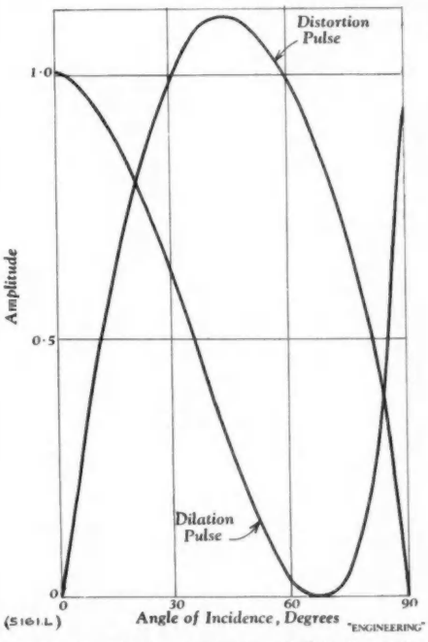


Fig. 9 Amplitudes of dilation and distortion pulses reflected when a unit dilation pulse meets a free boundary at various angles of incidence.

The results confirmed that the best agreement between the stress distribution occurring in practice and that calculated on static considerations would be obtained if it was assumed that the grips whereby the specimen was loaded remained fixed in position during propagation of the crack, rather than that the load was maintained constant. The grips should also be assumed to lie at a distance from the crack equal to one specimen width. A further difference between the dynamic case and the static analogue was that in the former small bending stresses developed near the crack; the transverse forces involved were balanced solely by the mass-acceleration of portions of the specimen near the crack.

Finally it was confirmed that crack velocities did not exceed 38 per cent of the longitudinal stress wave velocity, a result predicted by Mott from considerations of internal strain energy released by the fracture and kinetic energy associated with the stress waves radiating from the crack.

Mention should be made of the work of Schweiger and Zandman. Schweiger employed photoelastic methods to study transient stresses but used photoelectric instead of photographic recording. Stresses were set up in two glass rods of the same length and cross-section by striking one with the other longitudinally. At various points in the struck rod the stress was revealed photoelastically, the transmitted light being measured by means of a photoelectric cell and cathode ray oscillograph. The records enabled the magnitude and velocity of the stress waves to be determined and these were in satisfactory agreement with theory.

Photoelastic experiments, both static and dynamic, suffer from two disadvantages: the materials used in the analysis (mostly plastics of various types) are quite different from those used in construction of machines, and it is not always easy to reproduce experimentally the conditions which are met in practice. With these problems in mind, Zandman (France) has devised a method of studying the behaviour of metals or construction materials by means of what amounts to a photoelastic strain gauge. A thin layer of a thermosetting plastic which adheres well to metals and possesses bi-refringent properties is applied to the subject of investigation. The strains are measured by means of a beam of polarised light which passes twice through the film of resin being reflected at the surface of the subject. The reflected light is analysed in the usual way. Zandman points out that this technique should have great possibilities in studying elastic and plastic waves in metals, shock effects, cracks, brittle fractures, and fatigue, not merely in the laboratory but also in the factory.

CONCLUSION

The combination of high-speed cine photography and photoelasticity has proved valuable in showing up stresses in parts which are themselves changing in form as time goes on, even though the distribution of stress at any instant corresponds to that of static equilibrium. But the combination involving flash and spark photography which gave birth to true high-speed photoelasticity has proved to be immeasurably more valuable and more exciting. It has enabled the complicated interaction of stress waves and their reflections to be studied and the mechanisms

Production

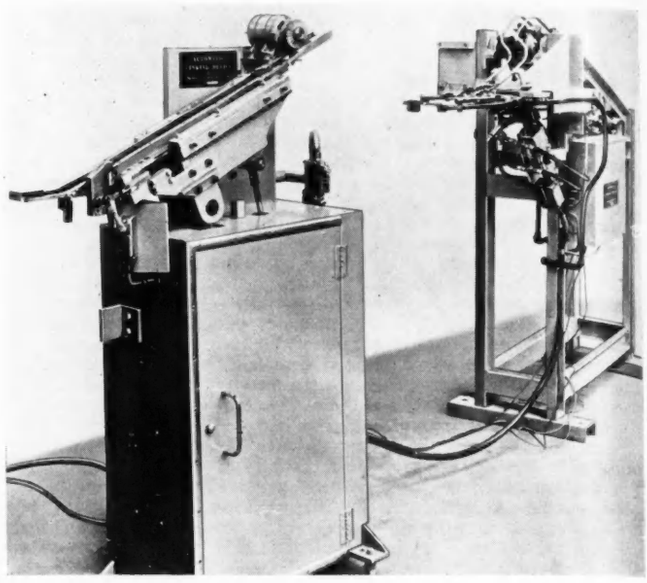
SPEEDING UP COMMUTATOR ASSEMBLY

Automatic machines for transferring components from one process to another are often an important link in a production line, and the types and varieties of such machines are increasing steadily. A recent introduction in this field is the transfer equipment made by the Hymatic Engineering Company Limited, Redditch, Worcestershire, for use in a line producing motor vehicle starter parts.

Formerly, starter commutators were unloaded manually from an air press and placed on a conveyor, from which a second operator took them, passed them through a hydraulic press, and finally placed them on a rotary-table reaming machine.

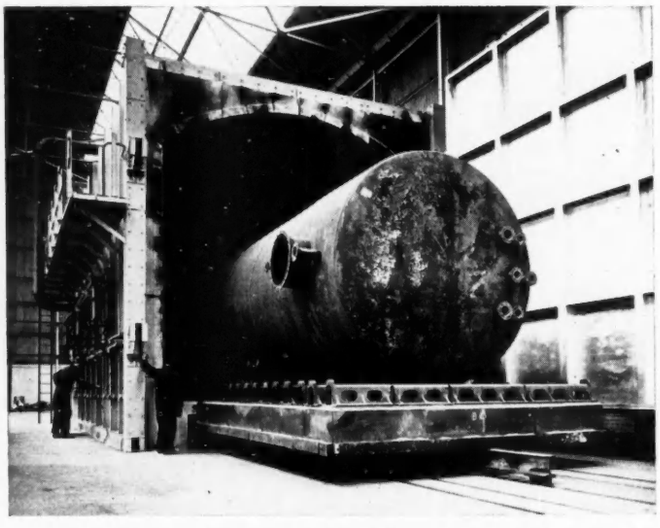
The commutators are now taken from the air press, which effects a slight spreading of the centre sleeve, and hand loaded on to a chain conveyor. This transfers the components to a pneumatically-operated feeding hand, which places them in the hydraulic riveting press, where the spreading operation is completed. A pair of rails then picks up the commutators and slides them into the chuck of the rotary-table reaming machine. Cam control on the rotary table ensures that the chuck accepts a commutator at the correct moment. To avoid any possibility of the various feed motions getting out of step, the cam on the reamer rotary table controls each feeding cycle separately, the hydraulic press acting as a slave. A small buffer stock of components may be built up on the chain conveyor, but they will be passed through the hydraulic press only at a rate at which the reamer can accept them.

The transfer equipment is pneumatically operated and electrically sequenced, the compressed air being taken from a mains supply at 80 lb per sq. in. It will operate at at speed of 500 components per hour, and was designed to fit in with the machines in their existing locations.



Electric starter components are handled at 500 an hour by the Hymatic electrically sequenced pneumatic transfer equipment.

WELDING AND STRESS RELIEVING FACILITIES



A new stress relieving furnace has internal dimensions of 16 ft 6 in by 16 ft 6 in by 35 ft long. Automatic temperature control is from 300° to 1000° C.

Recent additions at the Thorncliffe works, near Sheffield, of Newton Chambers and Company Limited, include a large stress-relieving furnace, an automatic welding machine, and new X-ray examination facilities, as well as extensions to the constructional shop. Though primarily for the use of the company's own engineering division, the new furnace will be available for the stress-relieving of vessels fabricated by other contractors. The internal dimensions of the furnace—one of the largest in the country—are 16 ft 6 in high by 16 ft 6 in wide by 35 ft long. With a movable door at each end, it is capable of taking vessels up 15 ft in diameter and 100 ft in length, weighing 60 to 70 tons. It is gas-fired, with an automatically-controlled temperature range from 300° C (for use in curing synthetic linings), to a maximum of 1,000° C (for the heat-treatment of stainless steel fabrications, etc.).

The electronically-controlled welding plant is the Union-Melt type of 2,000 A capacity. The associated manipulative equipment will facilitate the welding of vessels and fabrications up to 15 ft in diameter and 100 ft in length. The welding head is mounted on a cross-travel beam which is cantilevered from a column in the new extension to the construction shop. It has a cross-travel movement of 15 ft. The work is carried along on power-driven bogies—two of 20 ton and one of 60 ton capacity. There are three sets of fixed rollers and three sets of idler rollers which can be adjusted to accommodate cylindrical vessels from 2 ft to 15 ft in diameter. Each set of rollers has a carrying capacity of 20 tons, so there is capacity for a vessel of 120 tons. The rollers are mounted on a 145 ft long track and movement is electrically controlled to the required welding speed.

Continuing Research and Development

whereby fractures are caused by such stresses to be made clear. This is, to date, the principal contribution of the new technique.

Acknowledgments.—The writer would like particularly to acknowledge the help he has received from the writings of Dr. A. A. Wells on photoelastic theory, and many other workers whose names are mentioned in the text. He thanks the British Railways Executive, Imperial Chemical Industries Limited, Siemens Limited, and Kodak Limited for numerous references. Figs. 1, 5, 6 and 7 are reproduced with permission of the publishers of the *Philosophical Magazine*.

REFERENCES

[1] D. A. Senior and A. A. Wells, "Photoelastic Study of Stress Waves". *Phil. Mag.*, vol. 7, pp. 463-469 (1946).

[2] D. Post, "Isochromatic Fringe Sharpening and Fringe Multiplication in Photoelasticity." *Proc. Soc. Expt. Stress Analysis*, vol. XII, No. 2 (1955).

[3] D. Post, "Characteristics of the Series Interferometer." *Jour. Opt. Soc. Am.*, vol. 44, pp. 243-249 (1954).

[4] W. N. Findley, "The Fundamentals of Photoelasticity Applied to Dynamic Stresses." *Report* of Ninth Semi-Annual Eastern Photoelasticity Conference, May 13, pp. 1-11 (1939).

[5] H. C. Perkins, "Movies of Stress Waves in Photoelastic Rubber." *Jour. App. Mech.*, March (1953).

[6] D. G. Christie, "Reflection of Elastic Waves from a Free Boundary." *Phil. Mag.*, vol. 46, p. 527 (1955)

[7] F. C. Roesler, "Glancing Angle Reflection of Elastic Waves from a Free Boundary." *Phil. Mag.*, vol. 46, p. 517 (1955).

[8] D. G. Christie and H. Kolsky, "The Fractures Produced in Glass and Plastics by the Passage of Stress Waves." *Jour. Soc. Glass Tech.*, vol. 36, pp. 65-73 (1952).

[9] D. G. Christie, "An Investigation of Cracks and Stress Waves in Glass and Plastics by High-Speed Photography." *Jour. Soc. Glass Tech.*, vol. 36, pp. 74-89 (1952).

[10] A. A. Wells and D. Post, "The Dynamic Stress Distribution Surrounding a Running Crack: A Photoelastic Analysis." Naval Research Laboratory *Report* No. 4935 (April 1957).

BIBLIOGRAPHY

Coker and Filon, *Treatise on Photoelasticity*.

Frocht, *Photoelasticity*.

H. Kolsky, *Stress Waves in Solids*.

Actes du 2me Congrès International de Photographie et Cinématographie Ultrarapide, Paris, 1954.

Construction

MAKING THAMES WATER DRINKABLE

M.W.B.'s Ashford Common Filtration Works

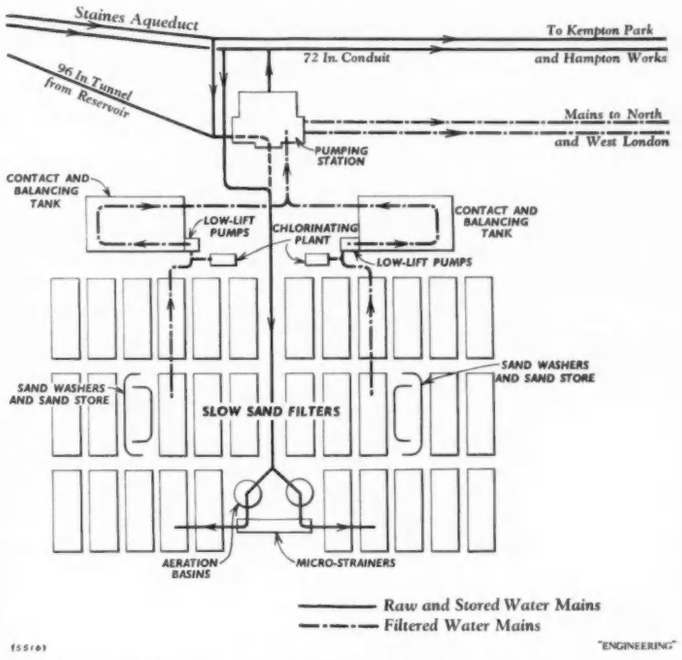
Hard experience has shown that slow sand filters are the most economic way of treating raw Thames water before supplying it for general use. Such filters have generally been superceded in waterworks practice by chemical sedimentation combined with rapid gravity filtration, but the Metropolitan Water Board (who are responsible for treating and distributing the water supply in much of the Greater London area) have reverted to the slow sand filter in the construction of their new Ashford Common filtration works. This works, which will treat 90 million gallons a day from Thames Valley reservoirs, is considered by the Board to be "the largest complete filtration and pumping plant ever to be constructed at one time in Western Europe." One wonders where in Eastern Europe there might be a larger. The works were officially opened on July 31 last.

Although, in using sand filters, there may be some reversion from current practice, the installation of micro-strainers which will handle the quantity of water involved is well in advance of contemporary experience. The micro-strainers used, there are 24 of them, remove most of the algae and coarse impurities from the raw water.

The main flow of water through the works, which can be traced on the accompanying sketch plan, is then as follows. Raw water for filtration will normally be drawn from the adjacent Queen Mary reservoir. For much of the time there is sufficient head in the reservoir to cause gravitational flow through the filter beds, but low-lift pumps have been installed that will enable the reservoir to be completely drawn down. These pumps have thereby increased the useful storage by some 2,000 million gallons, or 20 extra days flow through the works. The connection from the reservoir is an 8 ft diameter tunnel driven some 90 ft below ground level and lined with unreinforced concrete segments. Water can also be drawn off from the Staines Aqueduct which carries water from more westerly reservoirs to the Kempton Park and Hampton works; both these works can now be relieved of some of their load and the commissioning of Ashford Common will also allow two very old filtration works, those at Kew Bridge and Barnes, to be abandoned.

The first stage in the purification process will be two aeration basins where the water will be cascaded, as in a fountain, to increase its oxygen content and improve its quality by removing bad odours and tastes. This is the first works at which the Board has installed such basins.

From the aeration basins the water will pass through the battery of 24 micro-strainers. The drums of the strainers are 10 ft long by 10 ft in diameter, and the stainless steel mesh with which they are covered has about 76,000 openings to the square inch.



Layout, not to scale, of the Metropolitan Water Board's Ashford Common filtration works. The principal method of treatment is the 32 slow sand filters, each of which can pass 3¼ million gallons a day.

The next stage in the filtration process will be the slow sand filter beds (32 in number, each about ¾ acre in extent) of a type which has been used successfully for over 125 years to deal with Thames-derived water. The filters are composed of a layer of Redhill sand, 2 ft thick, supported by 3 in of fine gravel which rests upon a drainage system of porous (no-fines) concrete channels. The strained water enters at one end through a baffled inlet chamber from which it flows slowly on to the bed. It then passes down through the sand and gravel to the underdrains and is collected into two 66 in mains which lead to the chemical treatment plant. The maximum rate of filtration is 4 gal per sq. ft per hr, entailing a downward flow of 8 in an hour, or about 3¼ million gal per day through each bed. The capacity of the station is met with four beds out of action.

When a bed becomes choked by the micro-organisms which collect on the surface of the sand, it is laid off to be cleaned. Provision has been made for two kinds of mechanical cleaning. One method uses a hydraulic sand-washing machine carried on a gantry which can be travelled over each bed in turn. This equipment cleans the sand without actually removing it and without emptying the bed. The alternative method employs a travelling sand-handling bridge for use when re-sanding the beds. To facilitate cleaning, the surface of the sand is completely free from obstructions such as bell mouths or air vents; neither do inlets or outlets project into the beds; also, the valve houses are away from the edge of the bed and equipment for taking water samples is located in the valve houses.

From the filters the water passes to chlorination points and thence into the contact and balancing tanks. Superchlorination up to a maximum dose of 2½ parts per million is used, the chlorine being injected before the water enters the contact tank. The chlorine dose is varied automatically (according to the free chlorine present after contact) so that treatment is modified to suit the quality of the raw water being received and the rate of flow. Equipment has also been installed to permit the injection of either sulphur dioxide or ammonia. The former is used when it is required to reduce the chlorine content, the latter if it is desired to carry a residual of chlorine a long way into the distribution system.

The contact tanks are large concrete structures, covered with earth and sown with grass. Each has a store capacity of 5·8 million gallons, 2 million of which are for balancing the load on the filters. Each tank is divided into two sections by a full-height central wall, so that each half can be used in series to give the full contact period of two hours; or they can be used independently when either compartment has to be isolated.

At the end of the inlet pipes into the tanks there are fixed screens of stainless steel mesh (40 wires to the inch) which arrest any fauna or other unwanted matter. As the tanks are constructed above filter-bed level, water has to be pumped into them, and two small pumping stations do this.

From the contact tanks, the now treated water goes to the main pump house and into the mains, principally for distribution in the north and west of the Board's area. The main pumping station, situated at the north end of the site, houses low-lift machinery for drawing raw water from the reservoirs and high-lift pumps for delivering the purified water into the supply system. A large quantity of ancillary plant, particularly standby generating equipment, is also accommodated in this building. Extensive studies showed that plant with the lowest overall

WHEN WILL THE C.E.G.B. SELL WATER AS A BY-PRODUCT?

The commissioning of the Metropolitan Water Board's new treatment plant, described above, is an opportune moment for drawing attention to the general shortage of water for domestic and industrial use. Neither the collection nor the treatment of surface water is being made easier by the extension of industrialisation and the problems are also being increased by the growth in consumption *per capita*. Both in the United Kingdom and overseas, even where there is a plentiful rainfall, there may be considerable difficulty in providing adequate storage. Within the United Kingdom there is, for example, a serious objection to siting new industry and communities in parts of Essex, because there are no new conventional water sources to draw upon.

In coastal areas there is much to be said for making use of the sea as a water source. The cost of erecting and operating multi-stage distillation plant is becoming competitive with the expense of conventional reservoirs and treatment works. Overseas where the rainfall is insufficient such units offer what is perhaps the only solution to the shortage of sweet water. But even in areas with the necessary rainfall, distillation plant can be the most economic proposition. As an example of latter type may be cited the case of Guernsey—the first region with an adequate rainfall to order such a unit. The Guernsey plant is to be built by the Glasgow engineers, J. and G. Weir Limited, who have already supplied the plant producing three-quarters of the world's total output of fresh water from sea-water. The Weir unit has been fully described in ENGINEERING (vol. 185, April 25, '58, p. 531). Considerable advantages are to be won if distillation can be integrated with a source of waste heat from, say, a power station; in the future, the advantages can be most marked if the plant is linked with a power-producing nuclear reactor and the economics of such an arrangement were discussed in a subsequent article (vol. 185, 16 May, '58, p. 628). The time may well come when the Central Electricity Generating Board will supplement the activities of the water boards.

Continuing Construction

cost was an electric drive supplied by the grid, together with oil-engine driven alternating plant for standby and load-relieving duties. This has been done. An added advantage is the cleanliness of the electric drive, particularly at a filtration works. The Board are to be congratulated on the fine layout of the pump house and for excellent finishes, which together give an impression of spaciousness that is a model of good design.

Apart from the pumps, the main standby equipment includes three oil engines driving a.c. generators, each of 1,100 kW capacity (these machines have been glass cased to reduce the noise) and three gas-turbine driven a.c. generators. The gas-turbines have been installed by three different manufacturers so as to gain general experience of this type of equipment; one of the machines has now done some 2,000 hours of occasional running without giving trouble, and the other two are about to complete their service trials. Previous articles in ENGINEERING have referred to the plant at Ashford Common in some detail.* Even more detailed descriptions will be found in a paper by Mr. F. Wood, M.I.C.E., A.M.I.Mech.E., the Mechanical Engineer to the Board, published in the *Journal* of the Institution of Water Engineers for July, 1955. The civil engineering work was similarly described in a paper by Mr. F. Tattersall, M.Sc., M.I.C.E., the Board's New Works Engineer, published in the *Journal* of the Institution of Public Health Engineers for October, 1957.

Approval for the construction of part of the works was granted in December, 1947, and the remainder was authorised in September, 1949. All of the works were designed, and the subsequent construction and installation supervised, by the Board's engineering and architectural staff under the direction of the Chief Engineer, Mr. H. F. Cronin, C.B.E., M.I.C.E., M.I.Mech.E. The civil engineering work was carried out on a "cost plus fee with target" basis, and the mechanical and electrical plant was obtained by tender. The total estimated cost of the work is £5¼ million. A list of the principal contractors is appended.

General civil engineering and building works	John Mowlem & Co. Ltd.
Steel pipes and specials	South Durham Steel & Iron Co. Ltd. Clayton, Son & Co. Ltd.
Valves	J. Blakeborough & Sons Ltd. Guest & Chrimes Ltd.
Filtering media	Standard Brick & Sand Co. Ltd.
Micro-strainers	Glenfield & Kennedy Ltd.
Meters	Electroflo Meters Co. Ltd.
High-lift pumps, motors and Roto-valves	Harland Engineering Co. Ltd.
Low-lift pumps ..	Vickers-Armstrongs (Engineers) Ltd.
Low-lift motors ..	Metropolitan-Vickers Electrical Co. Ltd. Laurence Scott & Electromotors Ltd. Electric Construction Co. Ltd.
Reduction gear units ..	David Brown & Co. Ltd.
Gas turbines	Metropolitan-Vickers Electrical Co. Ltd. English Electric Co. Ltd. Brush Electrical Engineering Co. Ltd.
Oil engines	General Motors Corporation
Alternators	General Electric Co., Ltd.
Switch and control gear	Brush Electrical Engineering Co. Ltd.
Heating	Hope's Heating & Engineering Ltd.
Fire protection	Mather & Platt Ltd.
Cables and wiring ..	G. E. Taylor & Co. (London) Ltd.
Drainage pumps ..	Hathorn Davey & Co. Ltd.
Cranes	John Smith (Keighley) Ltd.
Transformers	Ferranti Ltd.
Oil engine acoustic booths	John Dale Ltd.
Mechanical sand handling and washing plant	Irving Engineering Co. Ltd.

* "Ashford Common Pumping Station: M.W.B. Adopt Gas-Turbine Stand-by Plant," vol. 179, 1955, p. 740. "Gas-Turbine Trials: Acceptance Tests on 2,500 kW Set," vol. 181, 1956, p. 141. "Reducing Engine Noise at Ashford Common Pumping Station: Enclosures for Diesel Generator Sets," by Dr. A. J. King, vol. 183, 1957, p. 16.

Engineering at Home

WHICH? *Consumer Research at Work*

In the first 10 months of their existence, the Association for Consumer Research Limited, 7 Great James Street, London, W.C.1, have developed a membership of 70,000. Now a critical time for the Association has been reached, as they will shortly be asking some 23,000 members, who joined in the first three months, to renew their subscriptions. The first issue of *Which*?, the Association's quarterly magazine containing reports of tests on goods and services available to the consumer, was published in October, 1957. The fourth issue has been published this month.

In *Which*? No. 3, a questionnaire was included giving members of the Association the opportunity to choose three items they would like tested. A preliminary analysis of the completed forms shows that detergents were selected as being the foremost class of substance requiring investigation: 25·3 per cent mentioned them as one choice. Paints came second with 13·1 per cent, followed by refrigerators with 10·3 per cent. Washing machines and electric light bulbs came sixth with 8·8 per cent each; television sets, fifteenth with 4·9 per cent; and fountain pens and ball point pens were twentieth with 3·3 per cent. As might be expected, there were differences in the selections made by men and women: the group cars, accessories, and petrol was chosen by 25·7 per cent of the men but by only 7·9 per cent of the women.

The present issue of *Which*? has among its contents details of tests on washing machines and ball point pens. There are many types of each of these products on the market, but, for practical reasons, it was not possible for the Association to test more than six electric washing machines. However, it is hoped that all types will be tested eventually, taking one group at a time. Tests made were intended to discover safety, sturdiness, convenience, and efficiency.

Tests on ball point pens were extended to 21 models, three samples of each being chosen. Some of the pens use the same refill and 15 types of refill were also tested. The prices of the pens tested varied between 1*s*. and 42*s*. Since a well-designed ball point pen should not leak at heights, the three pens and three extra refills of each make were subjected to the varying pressures that might be met up to heights of 15,000 ft. None of them showed any sign of leakage. To find out what would happen if the pens were kept in an inside pocket, at least six refills of each make were hung point downward in an oven at 90° F for 12 hours and inspected for leakage. After a further 12 hours, they were again inspected and, as a final check, the test was repeated at 120° F—a temperature which might be reached if the pens were left in the sun. Certain makes leaked after 12 hours at 90° F and continued to do so throughout the test. These were not subjected to further investigation.

To find out how long the ink supply in the different types of refill would last, and to compare their writing qualities at various stages throughout their lives, a writing machine was constructed to test all the types simultaneously. The pens were made to trace out a D-shaped curve on a moving sheet of paper: when 100 ft of paper had passed under the pens, each had traced out a line a mile long. The results showed that none of the types was completely free from a tendency to blot but some wrote more consistently and were largely free from thickening on the curves. The length of writing per refill was noted and the cost per mile calculated. Other items tested included the retracting mechanism, if present, the clip, security of the refill, strength of casing, visibility round the point, angle of writing, and ability to write on wet or greasy paper.

The Association conclude that eight of the pens can be recommended for their writing quality. They also list pens in order of preference for other qualities, which may be important for particular people; a mechanic, for example, may require a pen that will write over greasy finger marks. As far as the essential qualities of a ball point pen are concerned, the Association recommended two pens, both selling at 2*s*. 6*d*. each.

GOLF BALLS

An important specification in most ball games is the detailed description of the ball to be used. For such a description, it is necessary to know as much about the ball's behaviour in play as possible, and, to this end, measurements were made during the United States National Amateur Golf Championship at the Country Club, Brookline, Mass., to discover how a golf ball behaves on being struck. A simple drum camera was used, in conjunction with a stroboscope, operating at 9,000 flashes per second; at this rate, a golf ball travels about ¼ in between flashes. The stroboscope operation was photo-electrically synchronised with golfers' strokes. From the results so obtained, certain tentative generalisations have been made.

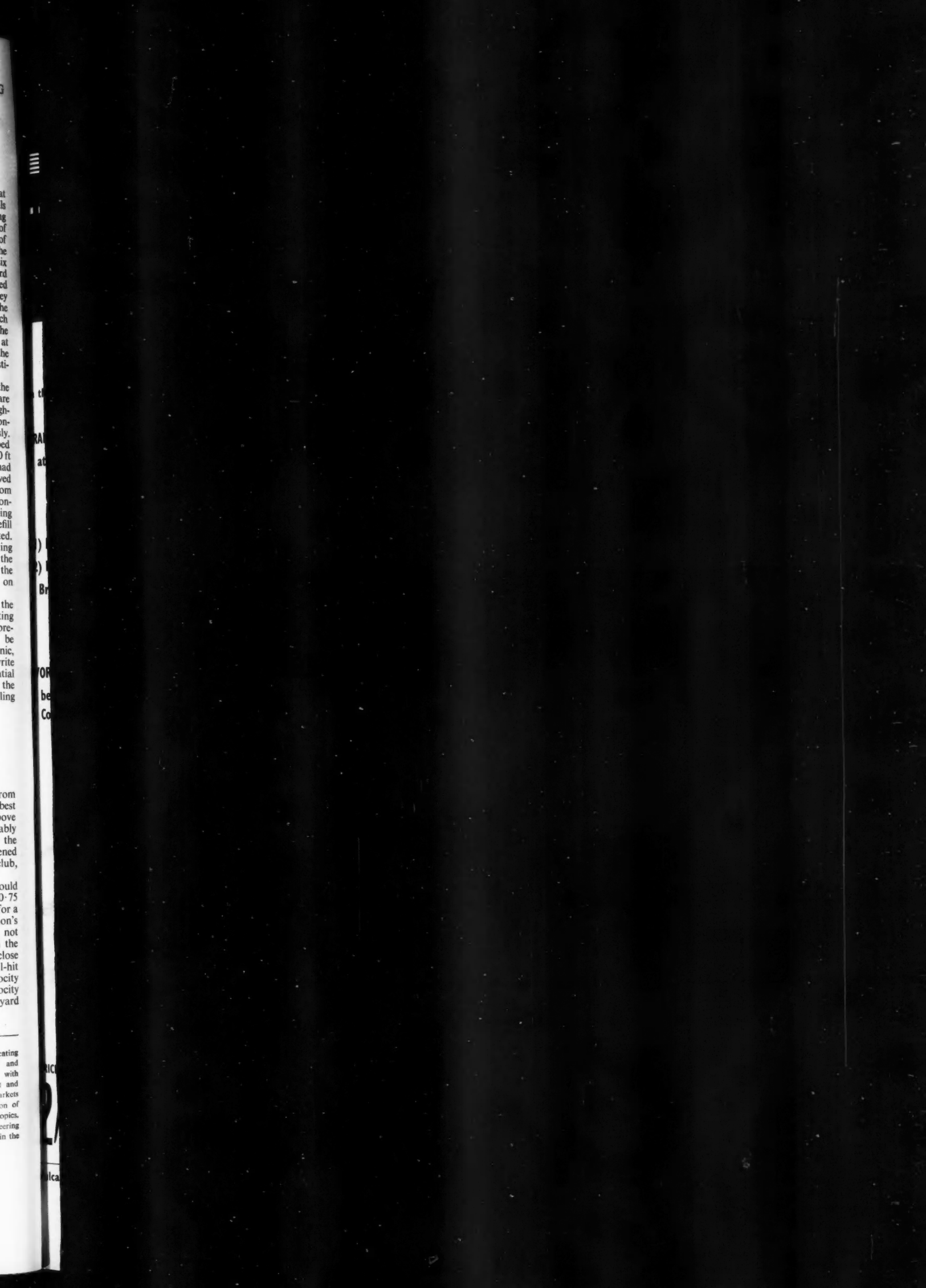
It appears that the velocity of the club at the bottom of a good golfer's swing does not vary significantly. There is, however, some variation in ball velocity, depending upon how squarely—rather than how hard—the ball is hit. From the tests, it seems that, for distance, the best angle of elevation of the ball is 11° or 12° above the horizontal. The hardness of a ball probably has little effect on the driving distance, and the photographs show that a softer ball is flattened more and stays longer in contact with the club, thus achieving better control.

The most efficient balls practicable would appear to have a coefficient of restitution of 0·75 to 0·80 for a very light impact, and of 0·65 for a hard one. The United States Golf Association's rules specify a test in which the ball shall not travel faster than 250 ft per second. From the photographic experiments, there is a fairly close correlation between the total length of a well-hit drive, including the final roll, and the velocity of the ball when it leaves the club. The velocity limit of 250 ft per sec corresponds to a 250 yard drive.

ENGINEERING

Published every Friday by ENGINEERING LTD. at 36 Bedford-street, London, W.C.2.
Telephone: Temple Bar 3663.
Telegrams: Engineering Lesquare London.

CHAIRMAN: J. A. Dixon, M.A., A.M.I.Mech.E.
EDITOR: F. B. Roberts, M.B.E., M.I.Mech.E., A.M.I.Loco.E.
DEPUTY EDITORS: D. Fisher, Ph.D., B.Sc., A.M.I.C.E., A.M.I.Mech.E.; E. P. Ward, M.A., A.M.I.Mech.E.
ASSISTANT EDITORS: E. I. Brimelow, M.Eng., Assoc.I.Mech.E., A.I.M.; J. E. Dodsworth; W. K. V. Gale, M.I.S.I.; J. T. Godfrey; R. Lemmy, A.I.M., M.I.S.I.; M. Neal, B.Sc., D.I.C., A.F.R.Ae.S.; R. G. Pay, M.Sc.; A. A. H. Scott, B.Sc., A.M.I.Mech.E.
SUBSCRIPTION MANAGER: G. A. Roberts.
ADVERTISEMENT MANAGER: G. H. Dixon.

Annual subscription rates: Inland and abroad £5 10*s*. (Canada, £5 5*s*.). Three months, 27*s*. 6*d*. all countries. Single copies, 2*s*. 7*d*. post free.

Engineering Information Service: Assistance is available from Engineering Information Service in obtaining information, and in locating sources of information, both technical and commercial. EIS deals, for example, with names of makers and suppliers of plant and equipment, technical data on design, markets for engineering products, and compilation of references to information on specific topics. Inquiries should be addressed to Engineering Information Service at the address given in the left-hand column.